ECOLOGICAL STUDIES ON SOME GREGARIOUS ACRIDOIDS OF AGRICULTURAL IMPORTANCE IN NORTH INDIA

ABSTRACT

THESIS

SUBMITTED FOR THE DEGREE OF

Doctor of Philosophy

IN

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THE ALIGARH MUSLIM UNIVERSITY, ALIGARH

BY

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ABSTRACT

The adults of *Acrida exaltata* and *Phlaeoba infumata* are found in short and tall grasslands, respectively. They migrate into crop fields when in advance stages while early nymphal instars remain within the grasses like *Cyperus rotundus*, *Seteria glauca*, *Paspalum distichum*, *Andropogon adoratus*, *Panicum psilopodium*, and *Cynodon dactylon*.

The adults are distinguished by the hind wings basally bright yellow and with a thick complete dark band and with the hind femur ventrally blue in *Acrida exaltata* while *Phlaeoba infumata* can be distinguished from its smaller size and incomplete hind wing fascia.

Both these species are found in a mixed population with each other at all stages. The life stages in laboratory conditions have shown that under constant conditions there can be four complete generations in a year, however, the number of generation may be reduced to 2–3 in natural population. Adults are found reproductively active in rainy season and in the months of September, October, March and April but do remain active in winter season without reproductive activities.

The act of copulation is on typical acridian pattern but with a longer duration of about 110 minutes in *Acrida exaltata* and 100

minutes in *Phlaeoba infumata* as compared to other acridids. Oviposition is completed in, on an average, 112 minutes in *Acrida exaltata* and 108.50 minutes in *Phlaeoba infumata* but it can be completed in 55 minutes and 75 minutes, respectively. The size of the egg–pods per female is variable in both the species, in *Acrida exaltata*, the average number of egg–pods per female was 3.68±0.11 (Isolated condition) and 3.12±0.12 (Crowded conditions) and the size of the egg–pod laid earlier was longer than laid later while in *Phlaeoba infumata* the average number of egg–pods per female was 3.28±0.01 (Isolated condition) and 3.00±0.13 (Crowded conditions).

The isolated and crowded conditions show some effect on the fecundity of these two grasshoppers. The average of eggs per egg–pod of these two species was found to be 25.09 (Isolated condition) in *Acrida exaltata* and 19.65 (Isolated condition) in *Phlaeoba infumata* and was also found different in both cases under crowded conditions.

Diapause does not occur at any stage of the life cycle, which indicates the presence of these grasshoppers through overlapping generations in a year. The development of hoppers and variations in the number of hopper instars have been observed as 5–6 in males in both the species while the number of female hopper instars varies from 6–8 in case of *Acrida exaltata* and 6–7 in *Phlaeoba infumata*. These variations were found even under constant conditions of temperature, humidity and food. In these two grasshoppers male individual cycle with 6 instar hoppers is completed in 43.53 days and 46.13 days while female cycle with 7 instar hoppers is completed in 55.83 days and 79.33 days in *Acrida exaltata* and *Phlaeoba infumata*, respectively and so such hopper duration is attributed to the number of instars in the cycle.

Dyar's law has been successfully applied under constant conditions of temperature, relative humidity, food and density.

The eggs of these two species are laid in moist soil and their development and percentage of hatching are greatly influenced by temperature and moisture. In *Acrida exaltata* the lowest percentage of eggs hatched was found to be 60.83% while the highest was found to be 76.14%. The incubation period was longest (51.53 days) at 25°C and the shortest (24.17 days) at 45°C. The development of eggs per day was calculated at 25 °C as lowest (1.98) and highest at 35°C (4.23). In *Phlaeoba infumata* the lowest percentage of eggs hatched was 63.49% at 25°C and highest was 86.67% at 35°C. Likewise, the average incubation period was longest (61.10 days) at 25°C while shortest (24.63 days) at 35°C and the development of eggs per day was slowest (1.66) at 25°C and highest (4.29) at 35°C.

The population level of these two grasshoppers is mainly influenced by temperature, relative humidity and available food plants. Both these grasshoppers are in abundance during rainy season from May to August in north India but their population dwindles when winters are approaching or terminating into summer but the adults remain active without reproductive activities.

The locomotory behaviour of hoppers and adults is greatly influenced by the environmental factors, mainly temperature, relative humidity, food, air speed and human activities. The temperature of the environment dominates the proceedings of the activities.

The food preferences of nymphs and adults have been found out and the factors influencing the food selection and the age-wise preferential values of food by the hoppers have been recorded.

The most important aspect of the present studies has been morphometry of these two grasshoppers in nymphal as well adult stages. All of the 21 measurements and 6 ratios are found statistically significant and sensitive to isolated and crowded conditions, confirming the instinctive gregarious behaviour though occasional in these two species. However, visual observations on few occasions on the gregarious and distinctive aggregation in *Acrida exaltata* and

Phlaeoba infumata are an additional confirmation to their unusual locust like behaviour. It is therefore, concluded and inferred that two economically important non–swarming, occasionally gregarious acridoids in north Indian soil are very close to become a permanent small sized locusts and may assume new dimensions of their dangerous posture.

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DEDICATED

TO

MY BELOVED PARENTS

&

MY RESPECTED DADIJAAN

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Ref. No. SKAR/17
Dated 20/9/2004

CERTIFICATE

This is to certify that Mr. Saiyed Mohammed Ali Badruddin has completed his work embodied in the thesis, entitled "**Ecological studies of some gregarious acridoids of agricultural importance in North India**" under my supervision. This is an original contribution and a distinct addition to the existing knowledge of the subject. It contains some very important new observations as well. He is allowed to submit the work for **Ph.D.** Degree in **Zoology (Entomology)** of the Aligarh Muslim University, Aligarh.

S. KAMAL A. RIZVI
Supervisor

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S.M. Ali Badruddin

(Saiyed Mohammed Ali Badruddin)

INTRODUCTION

CHAPTER – I

INTRODUCTION

No stretch of land is free from grasshoppers, which almost invariably become major pests of crops. Their devastations may be less spectacular than those caused by locusts but they are more persistent so that the effect on agriculture production and particularly on planned development is much more serious than caused by locusts.

The grasshopper problem in north India is assuming a new dimension and needs immediate attention in this regard. Therefore, the present problem was undertaken keeping in view the economic importance of two basically solitary grasshoppers, namely *Acrida exaltata* Walker and *Phlaeoba infumata* Brunner. Both species are occasionally gregarious and migratory in behaviour, though their ecological niches are different, but are found in close association. *Acrida exaltata* is commonly found in short grassland while *Phlaeoba infumata* is inhabitant of tall grassland and cultivated ground.

Acrida exaltata is a pest of rice (*Oryza sativa*), millet (*Pennisetum typhoides*), jowar (*Sorghum vulgare*), maize (*Zea mays*), gram (*Cicer arietinum*), groundnut (*Arachis hypogaea*), tomato (*Lysopersicum esculentum*), pinus (*Pinus roxburghii*), sal (*Shorea robusta*), sandal (*Santulum album*), and sugarcane (*Saccharum officinarum*). In the last few years it has become a major pest of millet, gram, maize, rice and sugarcane in northern India. On many occasions it was found attacking such crops with a gregarious behaviour.

Phlaeoba infumata is a pest of rice (*Oryza sativa*), maize (*Zea mays*), jowar (*Sorghum vulgare*), sugarcane (*Saccharum officinarum*) and citrus (*Citrus* spp.). Recently it has become a major pest of rice, maize and sugarcane and citrus plantations in northern India. It is also found in various behavioural phases while attacking such crops.

Since the bionomics, ecology and behaviour of these two very important pests is not known in detail except few occasional observations made by several workers, therefore, comprehensive study of life–cycle, ecology and behaviour and their natural enemies is urgently needed with special reference to the Indian sub–continent.

The effective control of locusts and grasshoppers, whether chemical or biological is intimately connected with the detailed ecology and biology of the species, and depends on a comprehensive knowledge of salient features in the bionomics and behaviour of an acridoid. A complete description of all stages of development may be of practical utility and without a thorough understanding of the relations between acridoid and their environment, effective control measures are not possible. There is no information available about the biology and behaviour of these two species especially in northern India where they are assuming the status of pests on the major crops. The present study was carried out in order to fill a gap in our knowledge of the ecology and biology of these pests. The study has been divided into three parts– namely biological, ecological and behavioural.

The biological parts are related to the life cycle and various stages while the ecological part gives information regarding population studies and relations with various environmental factors. The behavioural part deals with various behavioural patterns during biological processes with special reference to the feeding and reproductive behaviuour.

The present study is mainly based on laboratory studies. Some field observations on the seasonal variations and ecological conditions for both these species have also been included, in order to ascertain as to what factors they have in common for normal breeding and which may help in forecasting their ourbreaks and suggesting subsequent control measures.

The analysis of ecological data on population density would help the workers in finding seasonal trend and cyclical movements of these dreaded pests. The factors responsible for gregarization and swarm formations have been investigated. Such studies have been very exciting as to confirm the phase theory of locusts propounded earlier. These observations seem to be of great importance in the phase formation behaviour of acridoids in general.

Studies have been made on the bionomics, life–history, copulation, oviposition, feeding bahaviour and morphometrics, reproductive behaviour and colour patterns in one life–cycle and the phenomenon of multivoltine behaviour.

Ecological studies included the effect of temperature, relative humidity, food and crowding on *Acrida exaltata* and *Phlaeoba infumata*. During investigations various natural enemies have also been recorded for them, which may be exploited in the biological control of these acridoids.

REVIEW OF LITERATURE

CHAPTER – II

REVIEW OF LITERATURE

The studies on the locusts and grasshoppers have been carried out since the early twenties. Notable contributions in the field of Acridology concerning the present studies have been made by many acridologists.

The various modes of copulation and oviposition have been studied by several workers with their specific observations such as Katiyar (1952, 1955, 1956b) in *Eyprepocnemis roseus*, *Aularches punctatus*, *Oedaleus abruptus* and *Gastrimargus transversus*, Norris (1954) and Hunter–Jones (1960) in *Schistocerca gregaria*, Hafez & Ibrahim (1958) in *Acrida pellucida*, Pickford & Gillott (1972) in *Melonoplus sanguinipes* and Iqbal & Aziz (1974) in *Spathosternum prasiniferum*. Uvarov (1966) gave a detailed account of the common mode of copulation in acridoids, the 'riding mode' in *Schistocerca gregaria*. The copulation posture may differ in other species. Jhingaran (1944) recorded another mode of copulation 'lateral mode' in *Heteracris capensis*. Katiyar (1952) recorded a third mode of copulation 'hanging mode' in *Parahieroglyphus bilineatus*. Katiyar (1956b) also observed an intermediate mode of copulation between lateral and hanging mode in *Oedaleus abruptus* and *Gastrimargus africanus*. Popov (1958) observed in *Schistocerca* *gregaria* that copulating females continue to feed, crawl and jump during mating process. Pickford & Gillott (1972) in *Melanoplus sanguinipes* reported that female aggressiveness; female density and production of chemical attractant by the females are factors, which have a great influence on the selection of a mate. Most of the members of the sub–family Acridinae and Oedipodinae use acoustical means of communication during sexual activity (Haskell, 1958; Perdeck, 1958; Loher & Chandrashekharan, 1970 and Otte, 1970). Certain body parts like antennae, palpi, cerci, sense organs and some chemical stimuli and female sex attractants play an important role in the courtship activity (Jacobson, 1965; Thomas, 1965; Uvarov, 1966 and Pickford & Gilott, 1972). Pickford (1974) studied the reproductive behaviour of the clear winged grasshoppers, *Camnula pellucida*. Gregory (1965a, 1965b) in *Locusta* and Norris (1954) in *Schistocerca gregaria* observed the presence of more than one spermatophore in each female of these species which indicate the necessity of repeated copulation. Hunter–Jones (1960) reported that the last copulation in *Schistocerca gregaria* is the effective one. Singh & Dhamdhere (1984) observed the mating behaviour in rice grasshopper while Riede (1987) made a comparative study of pre–mating and mating behaviour in 25 species of South American grasshoppers belonging to 9 sub–families.

The type of soil plays an important role in the act of oviposition. It was observed that the females preferred to lay eggs in moist soil. In cases, where the soil is extremely dry female fails to oviposit at all (Norris, 1968; Edwars & Epp, 1965) and sometimes the female dies without egg-laying (Katiyar, 1956a). Katiyar (1955) in *Aularches punctatus* observed deposition of the eggs in sandy loam soil. Joyce (1952b) reported that the female of *Oedaleus senegalensis* prefers to lay eggs in clay soil. Pradhan & Peswani (1961) observed egg-laying in *Hieroglyphus nigrorepletus* in the roots of various shrubs. Chandra *et al.* (1973) made the detailed observations on the selection of soil type for oviposition in the migratory locust (*Locusta migratoria*) and studied the development of eggs deposited in the different soil types. The detailed process of oviposition has been described by Katiyar (1955, 1956a) in *Aularches punctatus* and *Parahieroglyphus bilineatus*, Hafez & Ibrahim (1958) in *Acrida pellucida* and Iqbal & Aziz (1974) in *Spathosternum prasiniferum*.

Norris (1950, 1952) studied the effect of crowding on the pre-oviposition period and interval of successive egg-laying in *Locusta migratoria migratorioides* and *Schistocerca gregaria* respectively. Antoniou & Hunter-Jones (1956) studied the effect of crowding on the fecundity of *Eyprepocnemis capitata*. Hunter-Jones & Ward (1959) studied the incubation period, instar hoppers and polymorphic behaviour in *Gastrimargus africanus* giving some effect of crowding on the sexual maturation of females, egg – laying rate, fecundity and viability of eggs. Lautie (1979) observed the fecundity of the females of *Locusta migratoria* in the absence of fertile males and Baloch (1980) made an observation on the pod crowding affecting viability of eggs in *Locusta* and *Schistocerca*. Pickford (1976) studied the embryonic growth and hatching of eggs of *Melanoplus bivittatus* in relation to oviposition date. Richards & Waloff (1954) studied the arrangement of eggs in the egg–pods of *Stenobothrus lineatus* and *Mecoseth grossus*. Ewer (1977) studied the function of the plug of egg–pods. However, Moriarty (1969) observed the decline of egg–laying capacity with the ageing of the female in *Chorthippus bruneus*. Fresa (1971) observed that the grasshoppers *Dichroplus elongates*, *D. pratensis* and *D. punctatus* were unable to oviposit and die without egg–laying due to the fungus *Entomophthora grylli*. Petty (1973) has mentioned that the hatching success is associated with the sand structure.

Choudhuri (1958) have made experimental studies on the choice of oviposition site by the two species of *Chorthippus*. Pickford (1960, 1976) noted survival, fecundity, population growth, embryonic growth and hatchability of eggs in *Melanoplus bilituratus* and *Melanoplus bivittatus* in relation to date of hatching, date of oviposition and weather conditions, while Pickford (1966b) studied the influence of date of oviposition and climatic conditions on hatching of *Camnula pellucida*. Bhatia & Singh (1961) observed the selection of oviposition site by the desert locust in relation to vegetation density. Smith (1968) reported the relationship between oviposition and fertility to copulation in *Melanoplus sanguinipes.* Khan *et al.* (1980) investigated the preferential behaviour for oviposition in *Chrotogonus trachypterus*. McCaffery & Page (1982) recorded the oviposition behaviour in *Zonocerus variegates*; Liu *et al.* (1984) stressed the selectivity for oviposition in locusts in China and an unusual oviposition behaviour in desert locust was recorded by Bhatti *et al.* (1986).

The variation in the size and shape of the egg-pods associated with the available moisture, food of the parent grasshopper, number of egg-pods laid previously as described by Norris (1950) while Hilliard (1959) attributed it to the soil. Khalifa (1957) recorded development of eggs with special reference to the incidence of diapause in the eggs of *Eyprepocnemis plorans*.

Bernays (1971b) provided some details about hatching process with reference to temperature, moisture and food for *Schistocerca gregaria*. Temperature, moisture and food have been reported to play an important role in successful hatching (Dempster, 1963). Agrawal & Rizvi (1982) observed an early emergence due to early monsoon in *Hieroglyphus nigrorepletus*, which is a diapausing species.

Resistance to desiccation among grasshoppers with reference to water loss on the hatchability of grasshopper eggs was studied by Salt (1952) while Pickford (1966b) observed the rate of mortality in extreme dry conditions. Hunter–Jones (1964) observed detrimental effect of high level of soil moisture, which may be due to restricted supply of oxygen. Shulov & Pener (1961, 1963) studied the incubation period in relation to moisture content. Shulov (1956) in *Anacridium aegyptium* observed the development of eggs extending for more than two months from normal time due to water deficiency. The mortality rate with extreme soil moisture level was recorded by Shulov & Pener (1961) and Harjai & Sikka (1970). Hunter–Jones (1964) in *Schistocerca gregaria* observed the eggs neither hatched in water–logged soil nor in almost dry soil. The eggs in dry sand die within two days but the water content of the sand in between these two extremes made no difference. Donaldson (1970) observed the difference between the top and the bottom eggs and between the resulting hoppers and adult populations of two strains of *Locusta migratoria migratorioides*.

The incubation period of eggs in *Chrotogonus* has been mentioned as inversely proportional to temperature and moisture but moisture affects the viability of developing eggs as noticed by Grewal and Atwal (1968). Church & Salt (1952) studied the normal development of *Melanoplus bivittatus* even at 12°C, while Hunter–Jones (1964) observed the reduction in hatching percentage at temperature extremes. Parihar & Pal (1978) attached significance to temperature on the development of eggs of surface grasshopper and Chapman & Page (1979) observed the mortality of *Zonocerus variegates* in Southern Nigeria. Hewitt (1979) laid stress on temperature and precipitation in the environment and their effects on the development of rangeland grasshoppers. Shulov (1952b) observed higher relative humidities as detrimental to one day old eggs. However, Shulov (1970) has given an importance of humidity in the development of eggs of Nomadacris septemfasciata and *Locusta migratoria migratotioides*. Berbays (1972) emphatically attributed the water content of the soil as an important factor in determining the size of hatchling in *Schistocerca gregaria*. Uvarov (1966) and Berbays (1971a) made a comprehensive study of the form and activity of vermiform larva of *Schistocerca gregaria*. Papillon *et al.* (1980) could find hormonal imbalance in *Schistocerca gregaria* with changing temperature. El–Ibrashy *et al.* (1985) have made some very useful observations on metabolic effects of juvenile hormones in the female desert locust.

Thomas (1980) observed the effect of casting temperature on *Palinia acuminata*. The account on the effect of temperature and humidity on the development of *Oxya hyla* by Mahto (1981) and by Ali (1982) on *Acrida exaltata* are of useful nature for further studies. Khousidjia & Fuzeau–Braesch (1982) observed the effect of temperature, grouping and isolation on several strains of *Locusta* *migratoria*, while Gregg (1983), Ingrisch (1983) and Kumar & Matin (1983) have investigated the effects of weather, humidity and soil moisture on various acridoids. Gregg (1984) presented a stimulation model of the development of *Chortoicetes terminifera* under fluctuating temperatures and Gregg (1985) stressed the temperature as an important factor in the embryology of diapausing Australian locust. Iheagwam (1985) observed wet & dry season Mendelian population of *Zonocerus variegatus* in Nigeria.

Studies on the effects of different degrees of temperatures and level of humidities on different stages of acridoids have been worked out by many workers like Grewal & Atwal (1968); Parihar (1971); Khan & Aziz (1973a, 1974c); Iqbal & Aziz (1973); Majeed & Aziz (1980a, 1980b) and Ali (1982). These workers have attributed temperature and humidity as an ecological factor responsible for the rate of development and hopper duration periods. Grewal & Atwal (1968) observed decrease in hopper duration of *Chrotogonus trachypterus* with the increase in temperature and relative humidity. Pradhan & Peswani (1961), while working with *Hieroglyphus nigrorepletus*, observed that the rearing at $32\pm1^\circ$ C was more favourable than at $26\pm1^\circ$ C at which the attainment of the adult stage has taken double the time and the development did not proceed at 20° C and 40° C. Similar observations are made by Parihar (1971); Khan & Aziz (1973a, 1974a, 1974c); Iqbal & Aziz (1973) in *Poekilocerus pictus*, *Oedaleus abruptus*, *Eyprepocnemis* *alacris* and *Spathosternum prasiniferum*, respectively. Abou-Elela & Hilmy (1977) observed the effects of photoperiod and temperature on the developmental stages of *Acrotylus insubricus*.

The effects of different levels of temperature and humidity on the development were studied by Grewal & Atwal (1968) with reference to pre-oviposition and oviposition periods in *Chrotogonus trachypterus*. Iqbal & Aziz (1973) recorded that the gonads mature earlier at 35° C and the female did not oviposit at 18°C and 45° C in *Spathosternum prasiniferum*.

In acridids the number of nymphal instars may vary from species to species and even in individuals of the same species (Joyce, 1952b and Katiyar, 1961). However, Hunter-Jones & Ward (1959) in *Gastrimargus africanus* observed variation in the number of hopper instars in male and female of the same species.

The distribution of grasshoppers in relation to vegetation and physical factors has been observed by Smith (1950); Abushama & Elhag (1971); Iqbal & Aziz (1975) and Moonis & Aziz (1977, 1980). Similar observations were made by Majeed & Aziz (1981b) while working on *Gastrimargus transversus* with reference to the effect of different food plants on the development of hoppers and their survival. Observations made by Ratan (1978) on the utilization of food by *Acrida exaltata* are of an informative nature. Khan

(1974) in his Ph.D. thesis on bionomics and life-history of some acrididae made preliminary observations on *Oedaleus abruptus* and its nutritional behaviour and Majeed (1978) in his Ph.D. thesis on ecological factors affecting *Gastrimargus transversus* had also made some observations on the importance of food plants as an ecological factor. Workers like Williams (1954) and Misra (1962) made some sporadic observations on the food patterns in grasshoppers. Abushama & Elhag (1971) have studied the distribution and food plants selection near Khartoum while Toye (1974) was able to record the feeding and locomotary activities of Zonocerus variegatus and Aziz & Aziz (1985) recorded plant selection pattern in *Oxya velox*. Useful studies were made by Bailey & Mukherji (1976) on the feeding habits and food preferences of Melanoplus bivittatus. Mulkern *et al.* (1969) had given comprehensive account of food habits of grassland grasshoppers of North Central Great Plains. Berbays *et al.* (1974) observed the inhibitory effects of seedling grasses on fecundity and survival of *Locusta migratoria migratorioides*, *Nomadacris septemfasciata*, *Chortoicetes terminifera*, *Melanoplus sanguinipes* and *Schistocerca Americana*. Misra (1962) observed that *Camnula pellucida* was able to discriminate nutritionally favourable plants from unfavourable ones. Rizvi & Aziz (1967) recorded the damage to vegetable and medicinal plants caused by *Oxya velox*. The intra species food preferences were studied by Ba-Angood & Khidir (1975) in *Schistocerca americana* and Iqbal & Aziz (1975) used twelve different food plants for food preferential values of different stages of *Spathosternum prasiniferum*.

Chabuike (1979); Ali (1981); Chandra (1981); Haniffa & Periasamy (1981) and Ronderos *et al.* (1981) observed some striking food preferences in African migratory locust, Bombay locust, desert locust, *Acrotylus insubricus* and Argentinian acridids, respectively. Manchanda *et al.* (1982) gave an impressive account of the host plants in relation to growth and development of *Schistocerca gregaria* while Chandra & Mital (1983) recorded similar observations in *Chrotogonus trachypterus*. Chandra & Chandra (1983) made a simple approach to rapid screening of plants for feeding preferences in *Schistocerca gregaria*. Food preferences for *Poekilocerus pictus* were investigated by Muralirangan & Muralirangan (1984) while Muralirangan & Muralirangan (1985) reviewed physico-chemical factors in acridid feeding. Ananthakrishnan *et al.* (1985) probed into food preferences in non – gregarious adults of *Schistocerca gregaria* and Chandra (1987) made some good observations on the food selection behaviour of desert locust. Very recently Chapman (1988) investigated the relationship between diet and size of the mid-gut in grasshoppers.

Smith *et al.* (1952) and Barnes (1955) studied the survival, fecundity and growth of the grasshoppers. Iqbal & Aziz (1977) observed the effect of different food plants on the development and reproductive potential of *Spathosternum prasiniferum*. The findings made by Toye (1973) and Bernays & Chapman (1973) on locusts are to be mentioned.

Barnes (1965) studied the effects of different food plants in terms of diet quality and its respective bearings on the health of the grasshopper. Manchanda *et al.* (1980) observed a new phenomenon related to the effects of host plant on the morphometrics and phase status of *Schistocerca gregaria* while Roonwal (1982) attached a biological significance to the pigmentation in the grasshoppers.

Effect of crowding on the development of grasshoppers and changing behaviour were studied by Norris (1950, 1952) in African migratory locust and desert locust, using crowded and isolated conditions but could not detect any difference in nymphal duration. Antiniou & Hunter-Jones (1956) found crowded conditions detrimental to the survival of *Eyprepocnemis capitata* specially in the first instar hoppers. Burnett (1951) studied the life-cycle of *Nomadacris septemfasciata* in relation to solitary phase while Staal (1961) observed the development of *Locusta migratoria migratotioides* in relation to crowded conditions. Hunter-Jones & Ward (1959) found rearing density having no effect on the adult morphometrics in *Gastrimargus africanus*. The density among adults of *Gastrimargus africanus* have no relevance with sexual maturation. This is in contrast to the observations made by Norris

(1950, 1952) and Hunter–Jones (1958) in locusts. Norris (1962a) made observations on the density and grouping effect on sexual maturation, feeding and activity in caged *Schistocerca gregaria*. Cassier (1972) observed the influence of rearing conditions (Isolated and Crowded) on the fecundity of females of *Locusta migratoria migratorioides*. Papillon (1972) also studied the influence of crowding of adults on their fecundity and polymorphism in their progeny while working on *Schistocerca gregaria*. Khan & Aziz (1974b) observed the effect of crowding on the hopper developmental periods on *Oedaleus abruptus* and *Eyprepocnemis alacris* under controlled conditions. Rizvi *et al.* (1975) observed the effect of crowding on the nymphal duration of *Hieroglyphus nigrorepletus*. Majeed & Aziz (1977, 1981c) observed the effect of crowding on the fecundity and viability of eggs and development of different stages under different density at constant temperature and relative humidity. Moonis & Aziz (1978) studied the effects of crowding on the development and fecundity of *Trilophidia annulata*.

The studies on the phase polymorphism and morphometrics of locust were made by several workers. Dirsh (1951, 1953); Roonwal & Nag (1951) and Misra *et al.* (1952) gave several measurements and ratios for characterizing phases in locusts. Key (1950) made a valuable critique on the phase theory of locusts. Blackith (1957) experimented polymorphism in some Australian locusts and grasshoppers. Stower *et al.* (1960) also studied the morphometrics in desert locust. Ellis (1951) studied marching behaviour of hoppers while Denis *et al.* (1976) recorded morphometrical changes in *Locusta migratoria* in relation to density. Ellis (1962) noted behavioural differences of locusts in relation to phase and species. Tanaka (1982) studied the crowding effects on the migratory locust in Japan. Chandra (1983) observed a small concentration of *Oedaleus senegalensis* in Rajasthan desert, which is of great importance in desert locust populations in relation to habitats. Basit *et al.* (1984) reported morphometrical changes of significant nature while rearing *Gastrimargus africanus.* Bellinger & Pienkowski (1987) investigated developmental polymorphism in red–legged grasshopper in USA. Rafeeq & Rizvi (1989) and Razak & Rizvi (1989) have made some observations on the suspected gregariousness in *Oedaleus senegalensis* and *Acrida exaltata*, respectively.

Environmental conditions play an important role in the grasshopper population structures. It is correlated with food availability, ecological niche and changing temperature with photoperiod. Favourable ecological conditions are attributed to vigorous biological activities. Comprehensive work in this field has been done on different acridoids notably by Richards & Waloff (1954); Katiyar (1955, 1956b); Mac Carthy (1956); Edwards (1960); Pickford (1960, 1966a); Chapman (1962); Riegert & Pickford

(1963); Lea (1969); Smith (1969); Nakhla (1970); Pick & Lea (1970); Khan & Aziz (1973a, 1973b); Qayyum & Atique (1973); Descamps (1975); Majeed & Aziz (1975); Moonis & Aziz (1977); Haq & Aziz (1978); Duranton & Lecoq (1980); Ali (1982); Julka *et al.* (1982); Serjeev & Li (1982); Agrawal & Rizvi (1982); Basit *et al.* (1983); Hazra *et al.* (1984); Materu (1984) and Mital & Chandra (1984). These workers have investigated the ecological and biological aspects of various grasshoppers in relation to their habitats, environmental conditions and zoogeographical conditions. Paranjape (1985) gave special emphasis to behaviour analysis to feeding and breeding in orthopteroid insects while Singh *et al.* (1985) made some field observations on the seasonal abundance of *Atractomorpha crenulata.*

The recent work on the population fluctuations of locusts and grasshoppers, their pattern of distribution and abrupt changes due to competitive relationships had been done by El–Minshawy *et al.* (1978); Ting *et al.* (1978); Chapman *et al.* (1979). Mulkern (1980) and Farrow (1982) investigated population dynamics of Australian plague locust with reference to analysis processes, while in India, Parihar (1983) stressed seasonal variations in population of *Pyrgomorpha bispinosa.* Halder (1986) studied the population ecology of three acridids in West Bengal. Hugueny & Louveaux (1986) observed specifically aridity gradient and latitudinal variations in size in populations of *Calliptamus barbarus* while

Hewitt & Onsager (1988) studied effect of sagebrush removal and legume interseeding on rangeland grasshopper population. A new approach has been adopted by Johnson & Adla (1988) in studying spatial and temporal computer analysis for grasshoppers in Alberta and is considered a new technology for rapid mapping of variables and their use in computer models.

Agrawal & Rizvi (1982) observed the emergence of *Hieroglyphus nigrorepletus* just after winters in North India when the species was found throughout India as univoltine and only seen in monsoon season. Jago (1963) describing life-histories *Eyprepocnemis plorans* in different seasons of the year. Phipps (1968) made observations on ecological distribution and life-cycle of some tropical African grasshoppers. Khan & Aziz (1973b) and Majeed & Aziz (1978) studied the seasonal variation in the population of the hoppers of *Oedaleus abruptus* and *Gastrimargus transversus*, respectively. Descamps (1975) made observations on acridid population of the state of Veracruz in relation to climatic conditions.

Some good work on the life-history, life-cycle (laboratory as well as field conditions) for various species had been produced by Pener & Shulov (1960) for *Calliptamus palaestinensis*; Dudley (1961) for Locusts; Bhatia & Singh (1965) for *Schistocerca gregaria*; Riegert (1967a) for *Camnula pellucida*; Antoniou &

Hunter–Jones (1968) for *Eyprepocnemis plorans ornatipes*; Ibrahim (1970) for *Pyrgomorpha conica*; Ba–Angood (1976) for *Cyrtacanthacris tatarica*; Roonwal (1976) for *Hieroglyphus nigrorepletus*; Moonis & Aziz (1977) for Trilophidia annulata; Antoniou (1978) for *Humbe tenuicornis*; Baloch (1978) for Ailopus thalassinus; Haq & Aziz (1978, 1979) for Acrotylus humbertianus; Lecoq (1978) for Sudansese acridid; Duranton *et al.* (1979) for *Catantops*; Parihar (1979) for *Pyrgomorpha*; Gunnarsson (1980) for locusts; Ibrahim (1980) for *Heteracris*; Lecoq (1980) for West African acridids; MacFarlane & Thorsteinson (1980) for *Melanoplus bivittatus*; Onsager & Hewitt (1982) for rangeland grasshopper; Capinera & Sechrist (1984) for Colorado grasshoppers; Holmberg & Hardman (1984) for six species of Canadian grasshoppers; Chapman *et al.* (1986) for *Zonocerus variegatus*; Waloff & Pedgley (1986) for South American locust; Whitman (1986) for *Taenipoda eques*. Cherill & Begon (1989) laid special stress on the timing of life–cycle in a seasonal environment with reference to temperature dependence of embryogenesis and diapause in *Chorthippus bruneus*.

In the last ten years the work on Acridoids have been carried out with unsequential concepts. Species have been chosen as a model not to be investigated with special reference. Das *et al.* (2002) could record the effect of food plants on the growth rate and survivability of *Hieroglyphus banian* of no new concept involved therein. Similarly Das *et al.* (2001) had touched fecundity and fertility of *Oxya fuscovittata* without much inference.

Nath and Haldar (1992) while working on food preferences have given satisfactory results and they have given a touch to mortality rate in Acridoid with environmental cues. Dealing with nutritional ecology, Waldbauer & Friendman (1991) has published a good work on self–selection of optimal diets by insects that too will be applicable in Acridoids as well.

The available literature on other Acridoids have been scattered otherwise, and on total may give some useful observation of any use in Acridoids bio–ecology.

The Acridoids of undisputed agricultural importance, understudy, and available literature on them suggests that these two species *Acrida exaltata* and *Phlaeoba infumata* were totally neglected by entomologists in general and acridologists in particular. The following literature on these two species is self explanatory to the decision, why they were selected for this comprehensive study.

The biology of *Phlaeoba infumata* has never been investigated except Xu and Lu (1987) on biological characteristics of *Phlaeoba augusdoris* and of no significance to get any idea of *Phlaeoba* biology. Some observations of no value taken by Gupta and Vats (1980) on food consumption remain uncompleted to the concept. The first report by Khan *et al.* (2003) on *Phlaeoba infumata* regarding damage done to medicinal plants appear to be important in the field of Ayurvedic and Unani medicine and their respective further studies.

Likewise, the work on *Acrida exaltata* and available literature shows that there is no information on any aspect of its life and living except scattered report by Ali (1982), Dwivedi *et al.* (1987), Garlinge *et al.* (1991), Golemonskey *et al.* (1998), Lo (1992), Patel and Dwivedi (1997), Zhong *et al.* (2001) regarding reports on the attack on some plants or any one biological aspect in fragment or biological control possibilities through nematodes, respectively. In total there is no information on bio-ecology of *Acrida exaltata.*

Literature available on acridid colouration spectra having no evidence going to be related to the concept created by Rizvi (1985) as an ecological bioindicator phenomenon. Later on some sporadic reports on colouration associated with microhabitat or as behavioural pigmentation depiction or as a cryptic behaviour presentation by Colvin and Cooter (1995), Eterovick *et al.* (1997), Islam (1998), Konno (1998), and Sword and Simpson (2000). But recently Badruddin *et al.* (2003) and Khan *et al.* (2003) have experimentally proved that the acridid colouration under abiotic and biotic factors can be used as bioindicators for the environmental changes.

There is no information on colour pattern of *Phlaeoba infumata* but few fragmentary reference work has been reported by Sobolev (1990) as characteristics of the cryptic behaviour but not based on experimental basis while Suresh and Muralirangan (1995) mentioning colour morphs of *Acrida exaltata*, just a report.

During present studies, certain experiments have been conducted and the preliminary observations are of great significance as per concept of being bioindicators, may be of ecological importance to acridologists in future.

Therefore, looking at the available literature, the present work may prove the complete investigation profile on these two important species of the sub-continent.

Rizvi *et al.* (2003) and Khan *et al.* (2003) have initiated to investigate the hitherto unknown observations on their biology and biological control and chromoecology.

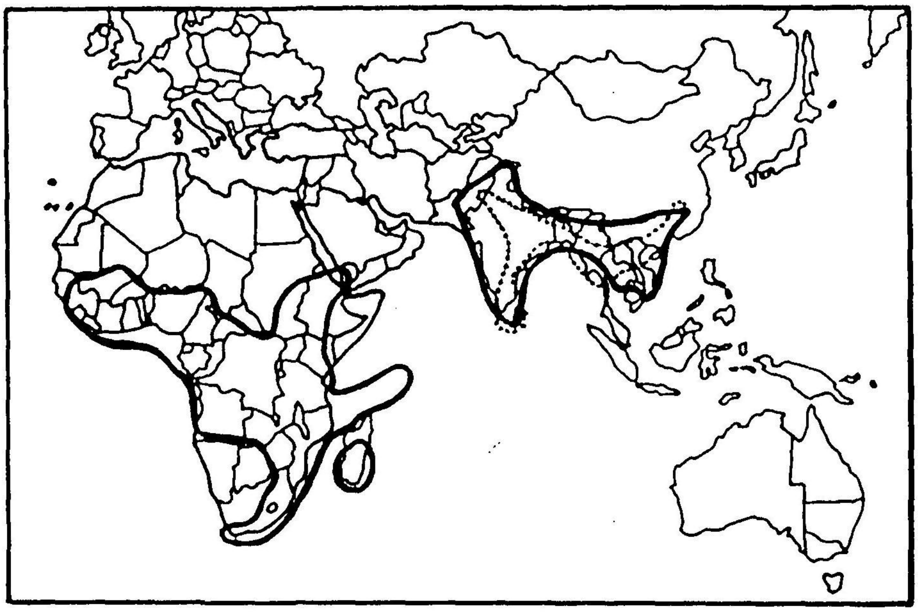

Fig.1. Distribution of:
Acrida exaltata Walk. (......)
Phlaeoba infumata Brunn.(......)

MATERIALS AND METHODS

CHAPTER – III

MATERIALS AND METHODS

Large number of mature adults and immature stages of *Acrida exaltata* Walker, and *Phlaeoba infumata* Brunner, were collected from different areas of Aligarh, Lat. 27 ° 34' 30" N and Long. 78° 4" 26' E (Fig (2, 3). They were reared in wooden cages (36cm × 36cm × 36cm) with glass panel on one side. Cages were provided with holes for metallic egg–laying tubes and an electric bulb (60 Watt) for light and heat. These cages were not thermostatically controlled but the heat could roughly be regulated by changing the number and, wattage of the electric bulb in the cage served two purposes, such as heat and photoperiod. Each cage was provided with a number of sticks for perching and moulting and also for basking. A petridish of water covered with perforated zinc sheet was kept in each cage and refilled as often as necessary, to keep the humidity at the desired level (Fig. 4).

The entire work was subdivided into five portions such as biology, population studies, environmental effects, gregarization and natural enemies.

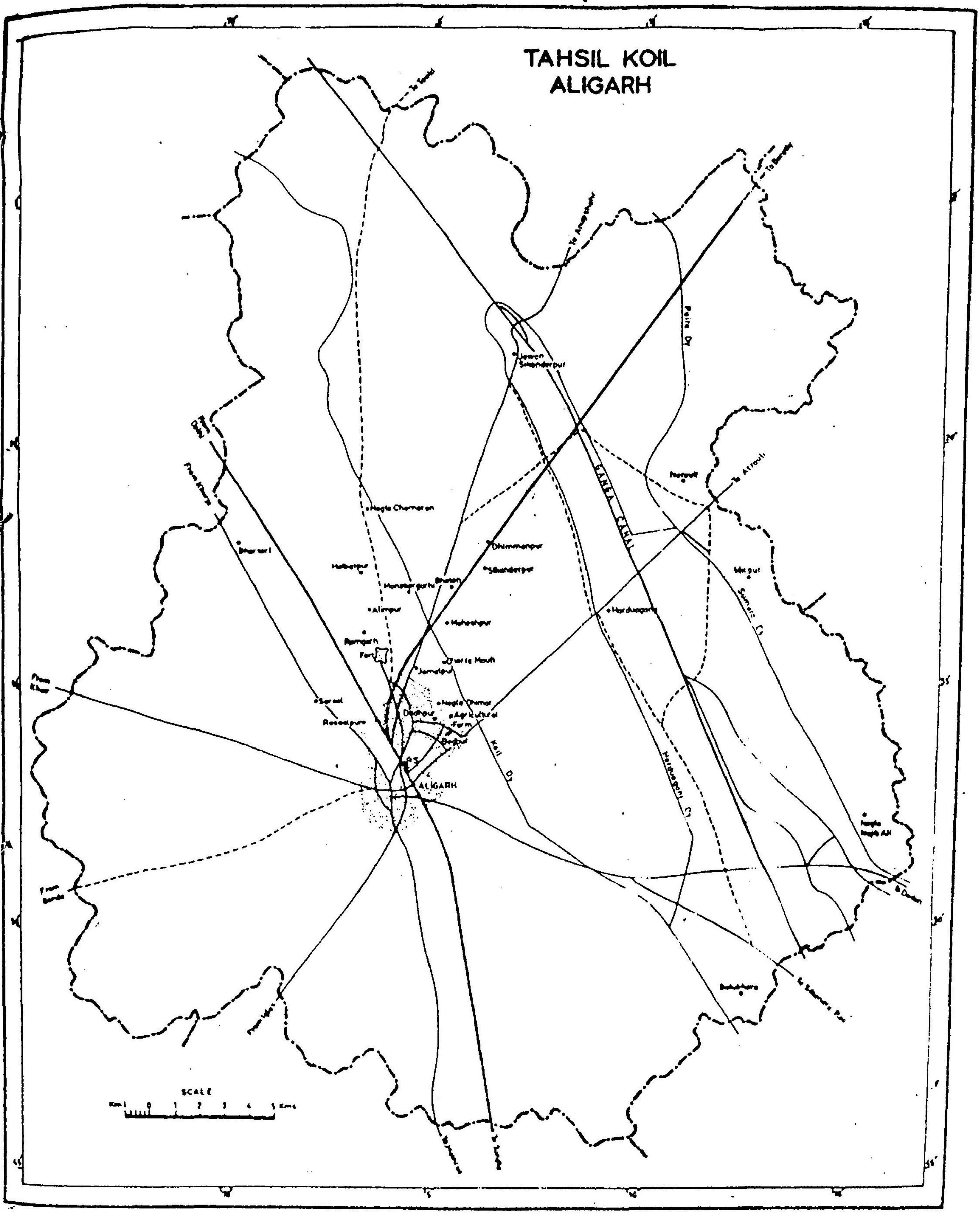
TAHSIL KOIL
ALIGARH
GANGA CANAL
ALIGARH
Fort
Dodhpur
Agricultural Farm
Jamalpur
Naglo Chamar
Rasalpure
Sarsol
Ramgarh
Alimpur
Bhatan
Sikanderpur
Dhimmanpur
Mahoshpur
Harduaganj
Nagla Chamaran
Jawan Sikanderpur
Bhartari
Palta Dy
Koil Dy
Harduaganj Dy
SCALE
Kms

Fig.2

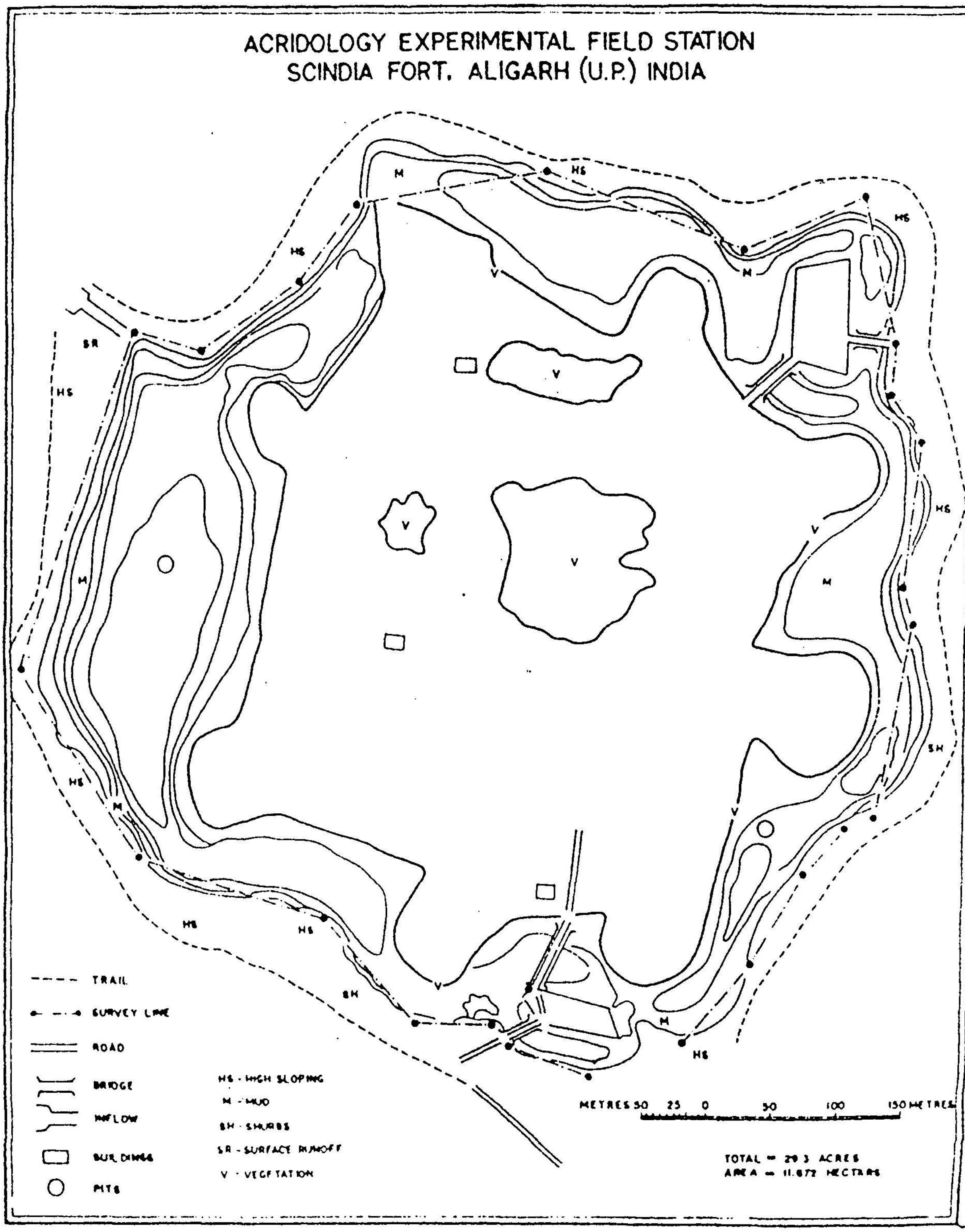
ACRIDOLOGY EXPERIMENTAL FIELD STATION
SCINDIA FORT, ALIGARH (U.P.) INDIA
TRAIL
SURVEY LINE
ROAD
BRIDGE
INFLOW
BUILDINGS
PITS
HS - HIGH SLOPING
M - MUD
SH - SHRUBS
SR - SURFACE RUNOFF
V - VEGETATION
METRES 50 25 0 50 100 150 METRES
TOTAL = 29.3 ACRES
AREA = 11.872 HECTARES

Fig.3

Fig. 4. Rearing cages in the laboratory

BIOLOGY

Adults were reared in wooden cages in the laboratory and the first generation was separated in two groups in which one was kept at constant temperature and humidity as per requirement while the other group was housed in field cages for natural biology (under field conditions).

The egg–laying tubes containing freshly laid eggs were separated into two batches, one for field and the other for incubators.

The daily temperature, relative humidity and rainfall in the field was recorded from the weather station, Department of Physics, A.M.U. Aligarh, which is hundred yards away from our field laboratory. The incubators were set at 10 °C, 25 °C, 30 °C, 35 °C, and 45°C with 70 ± 5 % R.H. for control conditions. The egg–pods were moistened daily according to the requirement.

The hoppers thus hatched were kept in glass jars and fed daily with fresh grasses. During individual as well as crowded rearing, observations were taken on all aspects of biology. On every stage of development, the morphometrics was done for the developmental rate and differences between various biological stages.

POPULATION STUDIES

The field observations on the population fluctuations were taken for three years (2001, 2002 and 2003). During different months of the year, random sampling and counting of the hoppers and adults were made. The counting method was based on sweeping technique. A standard net was used for the collection of grasshoppers. Observations were made every 15th day for an hour in a specified infested area. The data thus collected were analysed and monthly plotting of population in the form of a graph was obtained. The observations for three consecutive years were taken to avoid errors in any change in the behavioural pattern. As temperature, relative humidity and rainfall plays an important role in the occurrence of natural insect population, therefore, the monthly information about the meteorological conditions prevailing in Aligarh was taken from Physics Department, A.M.U. Aligarh for the above mentioned years and are being shown in the form of graphs. (Figs. 5, 6 and 7).

ENVIRONMENTAL EFFECTS

During the studies on the life–history, various environmental factors such as temperature, relative humidity, food plants and their effect on the biology of these grasshoppers were analysed to find

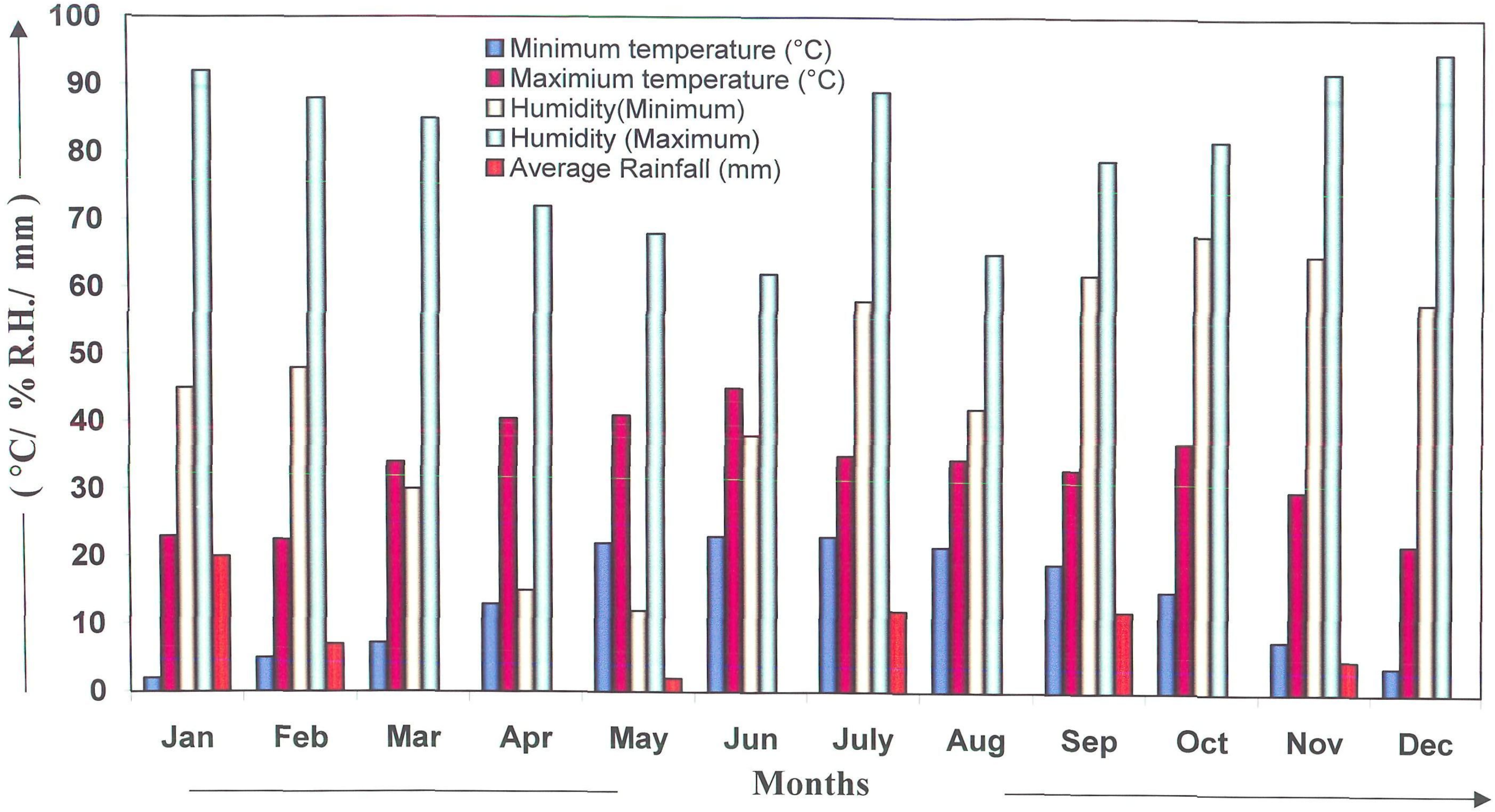

Fig. 5. Meteorological data of Aligarh during 2001

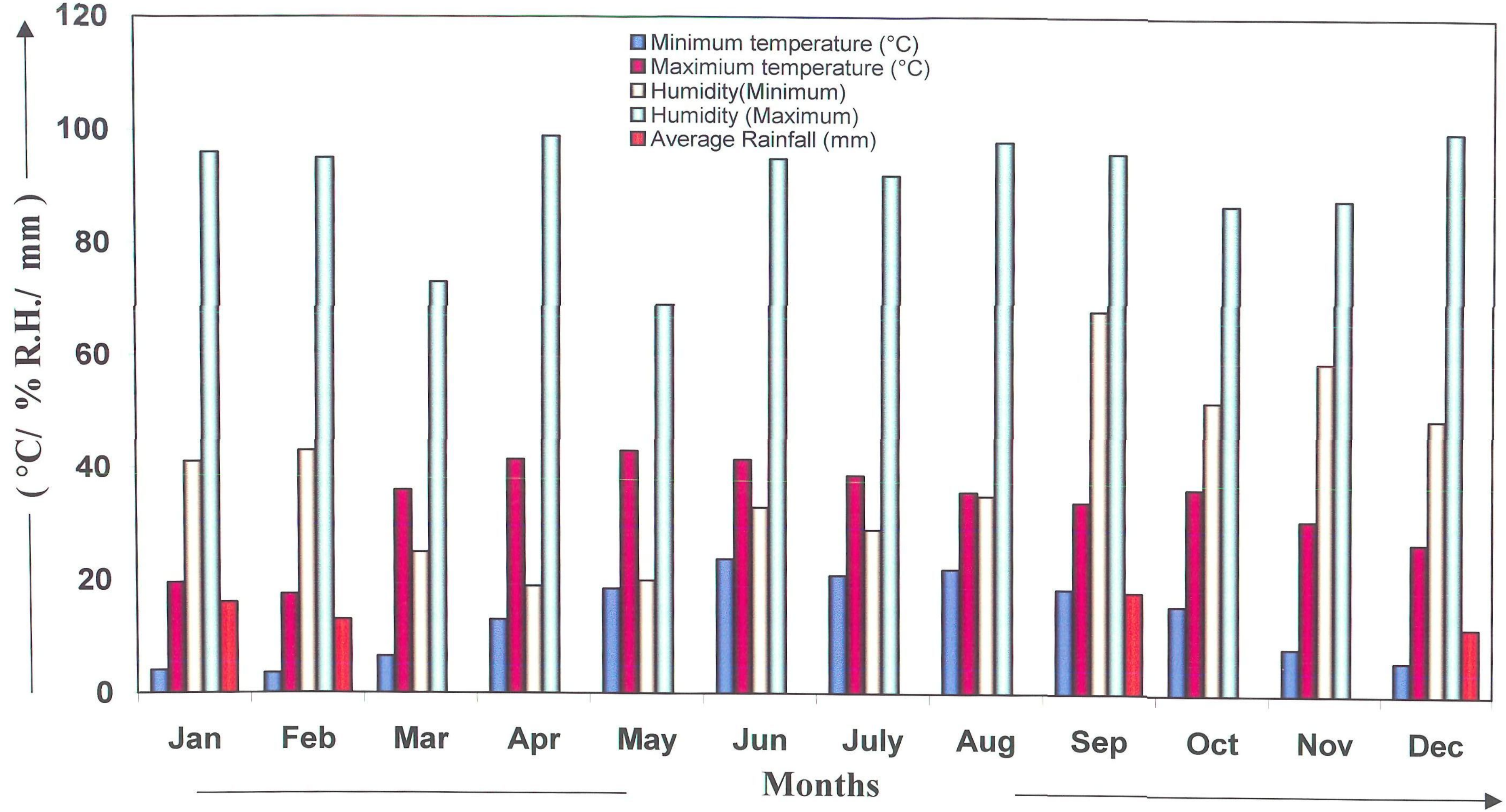

Fig. 6. Meteorological data of Aligarh during 2002

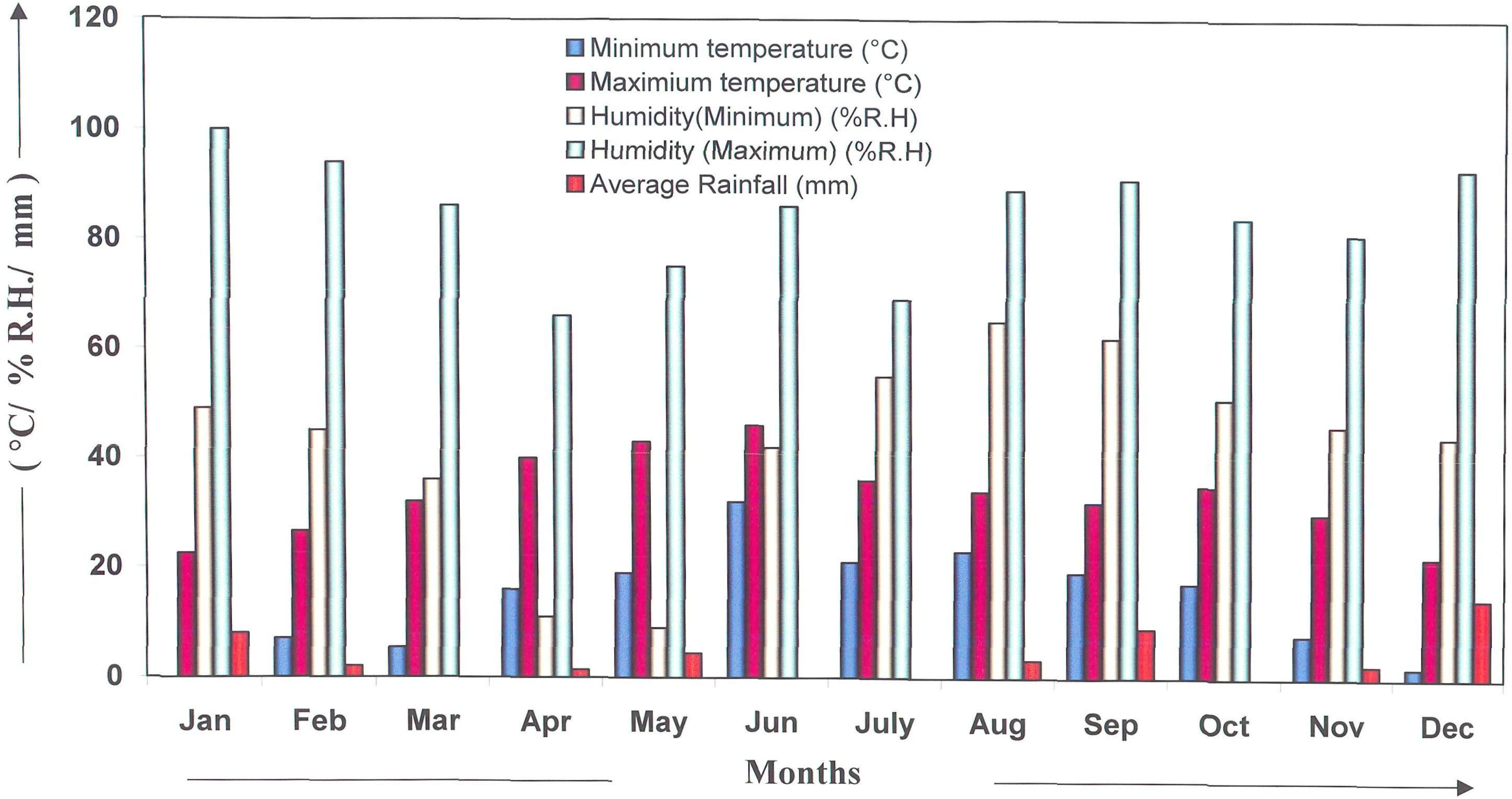

Fig. 7 . Meteorological data of Aligarh during 2003

any significant bearing of the ecological factors. To compare the natural and controlled conditions some experiments in the laboratory such as the effect of temperature, relative humidity and food plants on the incubation and copulation were computed and statistically analysed.

GREGARIZATION

The phenomenon of aggregation and gregarization was occasionally observed. Some morphometrical studies, based on body parts measurements with the help of micrometer and dial Vernier caliper, were undertaken. Morphometrical observations might be of immense value to establish the theory of phase formation of acridoids in general.

NATURAL ENEMIES

During the course of routine collection of these grasshoppers, various natural enemies were recorded such as earwigs, red–mites and various insectivorous birds and their potential effects were also observed. The data thus obtained will reveal the significance of such natural enemies in the possible biological control of these agricultural pests.

OBSERVATIONS

PART- I

Ecological studies on *Acrida exaltata* Walker

CHAPTER – IV

OBSERVATIONS

Part– I: Ecological studies on *Acrida exaltata* Walker

(A) BIOLOGY

(i) LIFE – CYCLE IN THE LABORATORY:

(a) Adult:

The adult of *Acrida exaltata* (Fig. 8A) is medium to long with slender body. Antennae relatively short with basal joints compressed, head strongly elongated, face strongly oblique, moderately concave in profile, more so in female. Pronotum with single median transverse furrow; lateral keels straight and slightly convergent anteriorly, slightly curved and divergent posteriorly. Tegmina and hind wings well developed; tegmina extend a little beyond hind knee, hind wings slightly shorter than tegmina. Hind femora long and slender with strong keels.

General colouration uniformly green or varying shades of brown. Hind wings light yellowish green, brownish over greater part of distal area. Darkening of the hind wing most pronounced in mature males.

A

B

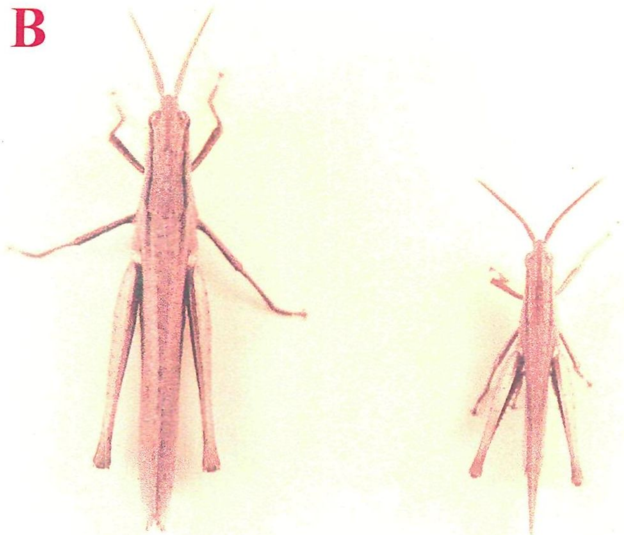

Fig.8. Male and Female showing natural colour and size

A – *Acrida exaltata*

B – *Phlaeoba infumata*

Measurements of Adults (mm):

	MALES	FEMALES
Length of the body	26.67 – 37.98 (31.00±1.02)	40.10 – 52.23 (48.73±0.62)
Length of pronotum	4.82 – 5.18 (4.94±0.17)	6.11 – 8.02 (7.96±0.18)
Length of tegmen	27.81 – 29.68 (28.50±0.06)	38.12 – 41.06 (39.77±0.22)
Length of hind femur	13.60 – 19.06 (18.79±0.11)	24.62 – 32.21 (29.86±0.82)

(b) Copulation:

The act of copulation in acridids is usually preceded by a more or less elaborate courtship behaviour, which has not been investigated as such in most of the acridid pests. The courtship involves brisk movement of antenna in both sexes with lateral touching of the body surfaces. Sometimes maxillary palps in face to face posture are touched by each other and lasts for about an hour. The courtship period ends with abrupt jumping of the male on the dorsal side of the female.

The copulating posture was found to be different in this case against continuous riding by the male on the female, which occurs in species with two sexes of similar size. Since the grasshopper

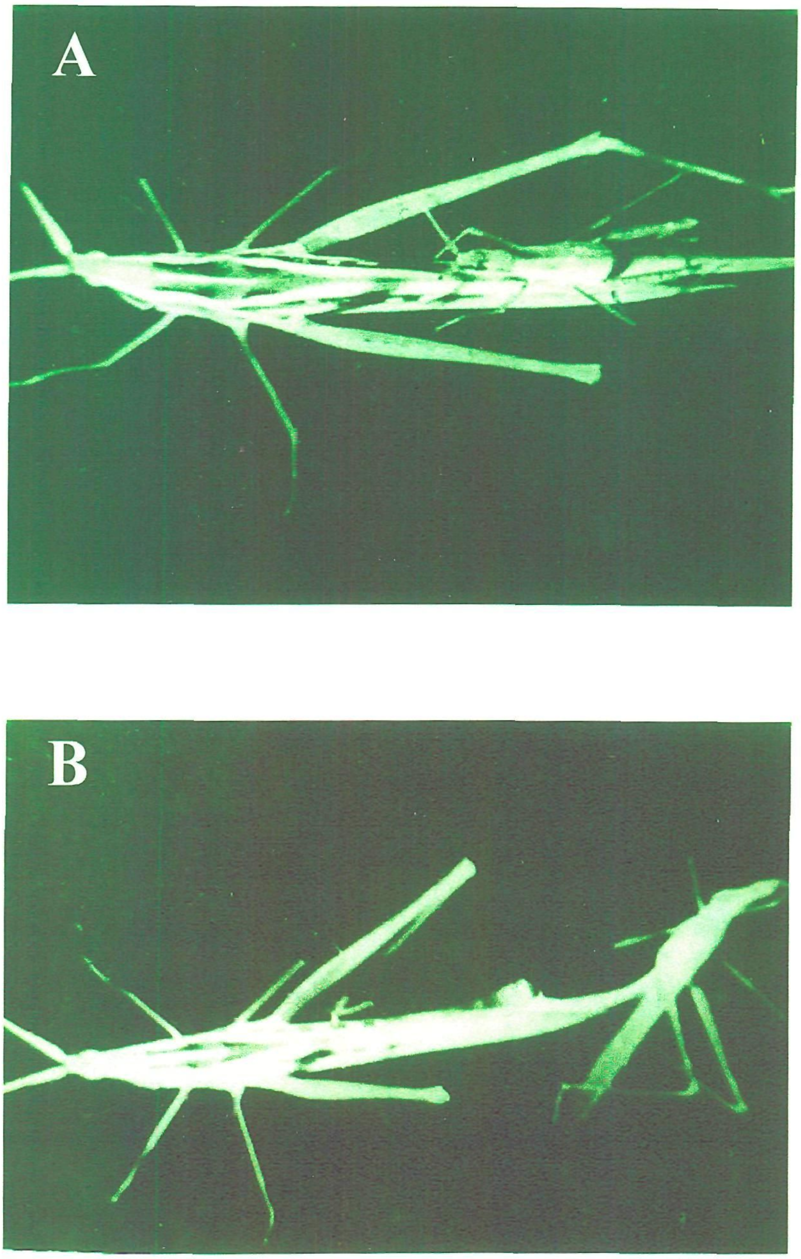

Fig.9. *Acrida exaltata*

A– Copulation posture
B – Riding posture

under study having different sizes in which male is smaller than the female and thus unable to reach the tip of her abdomen with his own and, therefore, might adopt a 'dorso–lateral' posture. Sometimes when the male was unable to copulate with the dorso–lateral posture then it attaches itself to the female in a hanging posture. It was also found that during the copulation the initial procedure was adopted as usual 'riding' posture, secondarily it was changed to dorso–lateral and thirdly in a hanging posture and finally back to back position on the ground (Fig. 9 A, B).

Though these findings are of academic interest but the present investigator attaches significance to the applied ecology related to control operation strategies. The period of copulation lasting about 40–110 minutes, which is sufficient time for control operations because this is the period when this acridid pest remains aggregated and sluggish (Table 1).

(c) Oviposition:

The oviposition ecology involves movements of female before the actual egg – laying is connected with searching, locating and probing for suitable conditions and successful egg–laying process. The mechanism involves in oviposition is on typical acridian patterns such as digging, making false holes and preferential behaviour regarding soil conditions. Some observations like period of oviposition, preferences towards soil, and fecundity of the individual female thus recorded may be of some applied interest for finding a suitable situation in control strategies. The time taken for egg-laying process was recorded as an average of 112.00 ± 12.18 minutes, while the minimum was 55.00 minutes and the maximum was 180.00 minutes, respectively (Table 1).

As pointed out, the structure of egg-pod indicates its considerable dependence on the oviposition habitat of the species particularly the soil condition. Thus in this species it was found that the position of the egg-pods in relation to the soil surface and changes in their depth was in accordance to soil texture. In one of the findings the number of egg-pods in three different soil conditions were counted and the recording shows much preference for mud as compared to sand and badarpur (Table 2). This observation is very useful from soil preferential value point of view and indicates the definite egg-laying sites of this species. The position of egg-pod has been different on different occasions. The egg-pods were straight where the watering of the egg-laying tube was without interruptions but in those egg-laying tubes where watering was delayed, the egg-pods were curved. This is probably because of soil moisture as indicated by earlier workers in some grasshoppers.

Table: 1. Time–table of Copulation, Egg–Laying and moulting processes

(10 replicates)

PROCESS	DURATION (MINUTES)	
	Acrida exaltata	*Phlaeoba infumata*
Copulation Period	40–110 (71.00±8.06)	45–100 (78.00±5.69)
Egg Laying Period	55–180 (112.00±12.18)	75–135 (108.50±6.75)
Moulting Time	15 – 45 (24.40±2.72)	12 – 25 (18.30±1.61)

Mean ± S.E. is given in parentheses.

Table: 2. Number of egg–pods laid by *Acrida exaltata* Walk. and *Phlaeoba infumata* Brunn. in different types of soils

NAME OF SPECIES	NAME OF SOIL			TOTAL EGGPODS
	Sand	MUD	BADARPUR	
Acrida exaltata	54	82	28	164
Phlaeoba infumata	45	56	32	133

Other methods of oviposition:

Basically the present species is hypodephic in nature but at times epidephic and epiphytic ovipositions are also recorded. The reason for this changing oviposition habit may be due to supermaturation of the gonads and failure in finding of suitable egg–laying sites. On few occasions it was found that this species oviposits in the broken stems of the plants with pithy centers as in case of *Chrysocraon dispar*, but the hatching was very frequently observed that if the female is unable to find the egg–laying tubes, it lays eggs on wood surface and wire mesh but they were found dried after short time.

(d) Egg–pod and eggs:

The size of egg–pod is mainly determined by the number of egg–layings per female. In this species the average number of egg–pod per female was found to be 3.68±0.11 (isolated condition) and 3.12±0.12 (crowded condition) and the size of the egg–pod laid earlier was longer than the egg–pod laid later. This may be due to decrease in the number of eggs.

The effects of isolated and crowded conditions on the fecundity of females of *Acrida exaltata*, (Table 48), show that there is a slight indication of their change in behaviour of egg–laying during aggregation. The average fecundity is also affected.

The measurements of egg–pod of *Acrida exaltata*, Table 3, are of much interest as it shows a range of measurements. Table 3 shows the actual length of egg–pod minus the length of froth. The average number of eggs per egg–pod was found to be 25.09±0.96 (isolated condition) and 20.40±0.74 (crowded condition). This clearly indicates that the average number of eggs per egg–pod, laid by a female, differs considerably under isolated and crowded conditions.

The majority of acridoids of temperate climates spend the longest part of their life–cycle in the egg stage, the same is true with *Acrida exaltata* which lives in a hot climate with a long dry period. During this dormancy the eggs can withstand the impact of adverse conditions.

(e) Incubation and hatching:

The incubation period of *Acrida exaltata* was studied at different temperatures (Table 4) with reference to hatching period of eggs. It was found that the suitable temperature was 35±1°C for the shortest incubation period. The incubation and hatching was

Table: 3. Measurements of egg, egg–pod and hatchling of *Acrida exaltata* Walk.

(10 replicates)

INDICES	MEASUREMENTS (mm.)
Length of egg	5.30–6.80 (6.44±0.18)
Width of egg	0.9–1.40 (1.19±0.13)
Length of egg–pod	44.10–58.50 (51.60±1.70)
Width of egg–pod	3.90–6.50 (4.57±0.28)
Length of hatchling	70.00–79.00 (76.11±1.00)

Mean ± S.E. is given in parentheses.

severely affected at $10\pm1°C$ and $45\pm1°C$. the results are given in Table 4.

The effects of isolated and crowded conditions on the viability of egg-pods and eggs and incubation period of Acrida exaltata at $35\pm1°C$ with 70 ± 5 % R.H were studied in order to ascertain the effect of crowding on the number of egg-pods, number of viable egg-pods, fertility, and mortality (Table 44). It shows that the crowding does affect the number, viability and the developmental frequencies of the eggs. This behaviour can be attributed to locust type behaviour shown by other locust species. In other words, it can be inferred that the crowding in *Acrida exaltata* puts the species in a stage, which can be called as 'locust in making'. The observations on the number of eggs hatched and their respective percentage, total incubation period inclusive of minimum and maximum and development of eggs per day in relation to five different temperature exposures ranging from $10\pm1°C$ to $45\pm1°C$ show tremendous ecological bearing of temperature on the hatching of this species. The average lowest percentage of eggs hatched (60.83%) was at $25\pm1°C$ and the average highest percentage of hatching went upto 76.14% at $35\pm1°C$. in both cases the relative humidity was 70 ± 5 %. Likewise the average incubation period was the longest (51.53 days) at $25\pm1°C$ and the shortest (24.17 days) at $35\pm1°C$. in the same manner the development of eggs per day thus calculated was the slowest (1.98%) at 25±1°C and the fastest (4.23%) at 35±1°C. There was no hatching at 10±1°C and 45±1°C (Table 4).

The role of temperatures as recorded under controlled conditions corresponds to that of natural conditions. It was observed when the atmospheric temperature was around 30°C and with 70.0% R.H., the hatching was at its maximum.

Miscellaneous observations:

During studies on egg mortality, the effect of high temperature on eggs was recorded as there was 100% mortality above 40°C and there was no hatching below 18°C. the resistance of eggs to low temperature and high temperature was investigated from the survivability of eggs of this species which is of much significance as they hibernate at that stage. When eggs were kept at −5°C for about 10 hours, the percentage of mortality was found to be 20–25%, while at 44°C for 20 minutes, the percentage of mortality was found to be 15–20%. This is a relevant observation, which can be attributed to the hibernation behaviour of the species at low temperatures and aestivation at higher temperatures. It was also noted that excess watering of egg–pods cause egg mortality.

Table: 4. Effect of different temperatures on the incubation period and hatching of eggs of *Acrida exaltata* Walk. at 70 ± 5% R.H.

Temperature (°C)	Total no. of egg–pods	Average no. of eggs/ pod	Total no. of egg counts	Incubation period (Days)	Development of eggs/ day (%)	No. of eggs hatched	Hatching percentage
10	25	24.60	615	-	-	No hatching	-
25	50	24.00	1200	51.53	1.98	730	60.83
30	45	24.44	1100	33.50	3.00	725	65.91
35	40	24.62	985	24.17	4.23	750	76.14
45	30	24.33	730	-	-	No hatching	-

The egg mortality was also recorded when the egg – laying tubes were exposed to solar radiation for about 8 hours a day and more severe mortality was observed when the muddy water was placed on top of the egg–pods.

(f) Development of hoppers:

According to Uvarov (1966) the term hopper may be regarded as a colloquial one, but it is less liable to mislead than such terms as nymph, or larva. In this text the word is being used for immature stages of the grasshopper before it becomes an adult.

The development of hoppers consists of growth associated with periodic moults. The first instar hopper, immediately after the intermediate moult, is called a 'hatchling' (Fig. 18). Its colour is yellowish–creamy or pale green and gradually becomes darker after few minutes.

The total growth of newly moulted hoppers was estimated by measuring the increase in the total body length and weight at the beginning of each instar, before feeding.

During hopper development an instar–wise weight of the hoppers and the rate of increase at successive stage was observed, and it comes to be 7–10 mg in case of male and female first instar hoppers. In the male, having five instars, the rate of increase in the body weight was found to be highest in third instar as 2.23 while lowest as 1.50 in the fifth instar. But female hopers, with 6 instars, have shown the rate of increase in body weight highest in the third instar as 2.23 while lowest as 1.48 in the sixth instar (Table 5, Figs. 10, 11).

The first instar hopper measures 8.96 mm and goes upto 29.27 mm in sixth instar in male, while in case of female the first instar hopper measures 9.34 mm and reaches up to 33.02 mm in sixth instar before becoming adult. The mean rate of increase of body length between instars in both sexes was calculated as 1.24 in males and 1.29 in females (Tables 6, 7).

The measurements of various body parts of the hoppers of *Acrida exaltata* were taken and the rate of increase in various instars in both sexes were calculated. Thirteen body parts thus measured were: the length of body; length of antenna; width of vertex between the eyes; vertical and horizontal diameter of eye; maximum width of head at genal level; length and height of pronotum; length of sternum; length of the anterior, middle and hind femur and width of hind femur.

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Table: 5. Instar–wise weight of *Acrida exaltata* Walk. and ratio of increase in various instars.

(10 replicates)

Instar	**Males**		**Females**	
	Weight (mg)	**Ratio of increase**	**Weight (mg)**	**Ratio of increase**
I	7.00–10.00 (8.40±0.37	–	7.00–10.00 (8.40±0.37)	–
II	12.00–20.00 (16.40±0.81)	1.95	12.00–20.00 (16.40±0.81)	1.95
III	21.00–45.00 (36.50±2.56)	2.23	21.00–45.00 (36.50±2.56)	2.23
IV	50.00–90.00 (74.80±4.80)W^+	2.05	55.00–95.00 (78.50±4.54)	2.15
IV	45.00–80.00 (63.40±4.04)W^-	1.74	55.00–95.00 (78.50±4.54)	2.15
V*	81.00–125.00 (104.60±4.04)	1.40	93.00–195.00 (139.10±11.56)W^+	1.77
V**	82.00–110.00 (101.40±2.72)W^+	1.60	90.00–140.00 (116.30±5.57)W^-	1.48
VI*	–	–	200.00–270.00 (241.70±7.50)	1.74
VI**	93.00–139.00 (113.90±4.59)	1.12	100.00–110.00 (148.50±12.95)W^+	1.28
VI***	–	–	95.00–150.00 (124.50±6.47) W^-	1.07
VII**	–	–	270.00–290.00 (282.30±2.07)	1.90
VII***	–	–	155.00–265.00 (211.00±13.25)W^+	1.69
VIII	–	–	285.00–415.00 (345.00±18.32)	1.64
Adult	127.00–172.00 (147.40±4.90)	1.29	411.00–794.00 (626.30±45.29)	1.82
Total	–	17.55	–	74.56

Mean ± S.E. is given in parentheses.

W^+ Reversal condition of alar rudiments.

W^- Non–Reversal condition of alar rudiments.

* Male with 5 hopper instars.

** Male with 6 hopper instars.

* Female with 6 hopper instars.

** Female with 7 hopper instars.

*** Female with 8 hopper instars.

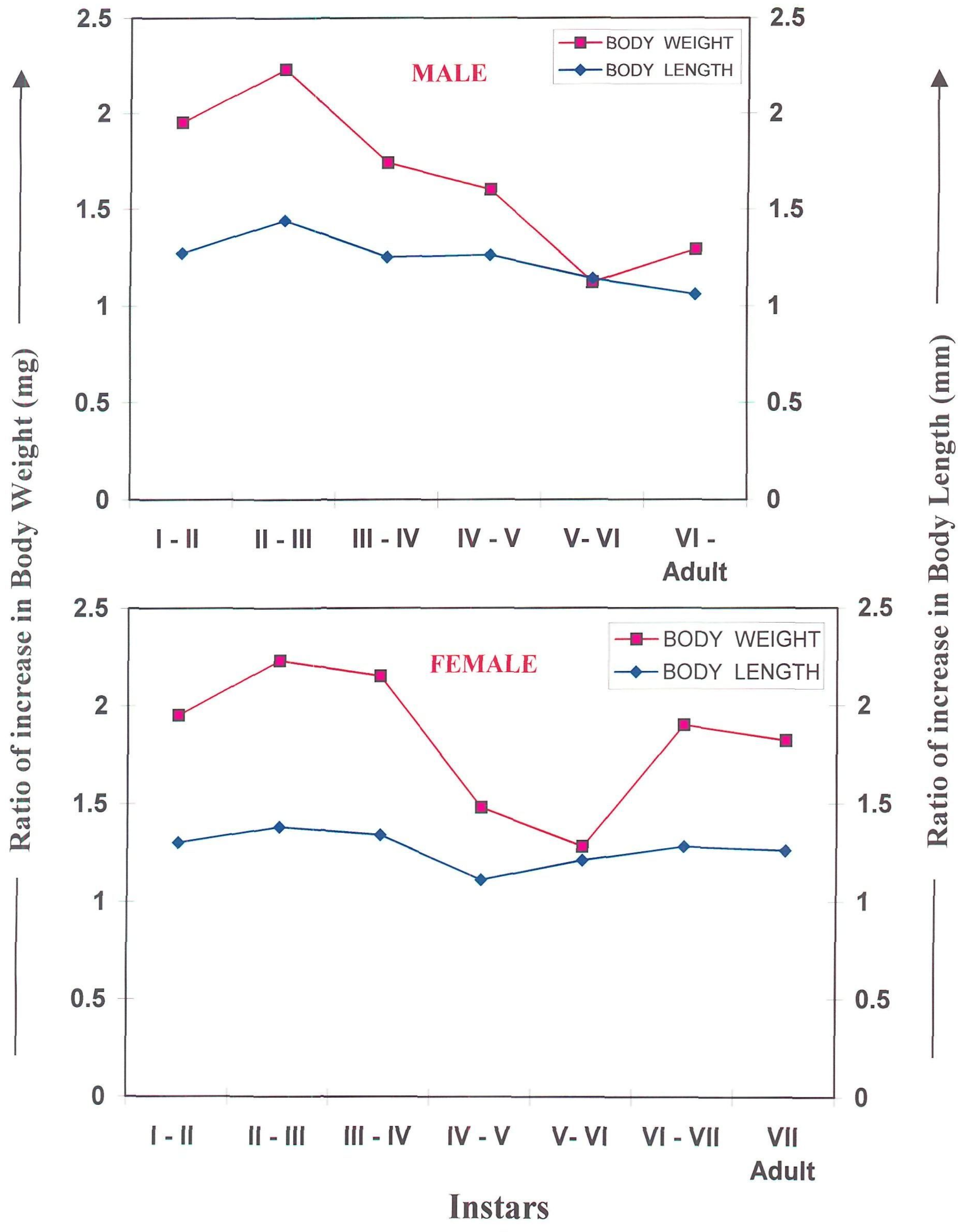


Fig. 10. Hopper growth of *Acrida exaltata* Walk. in length and weight

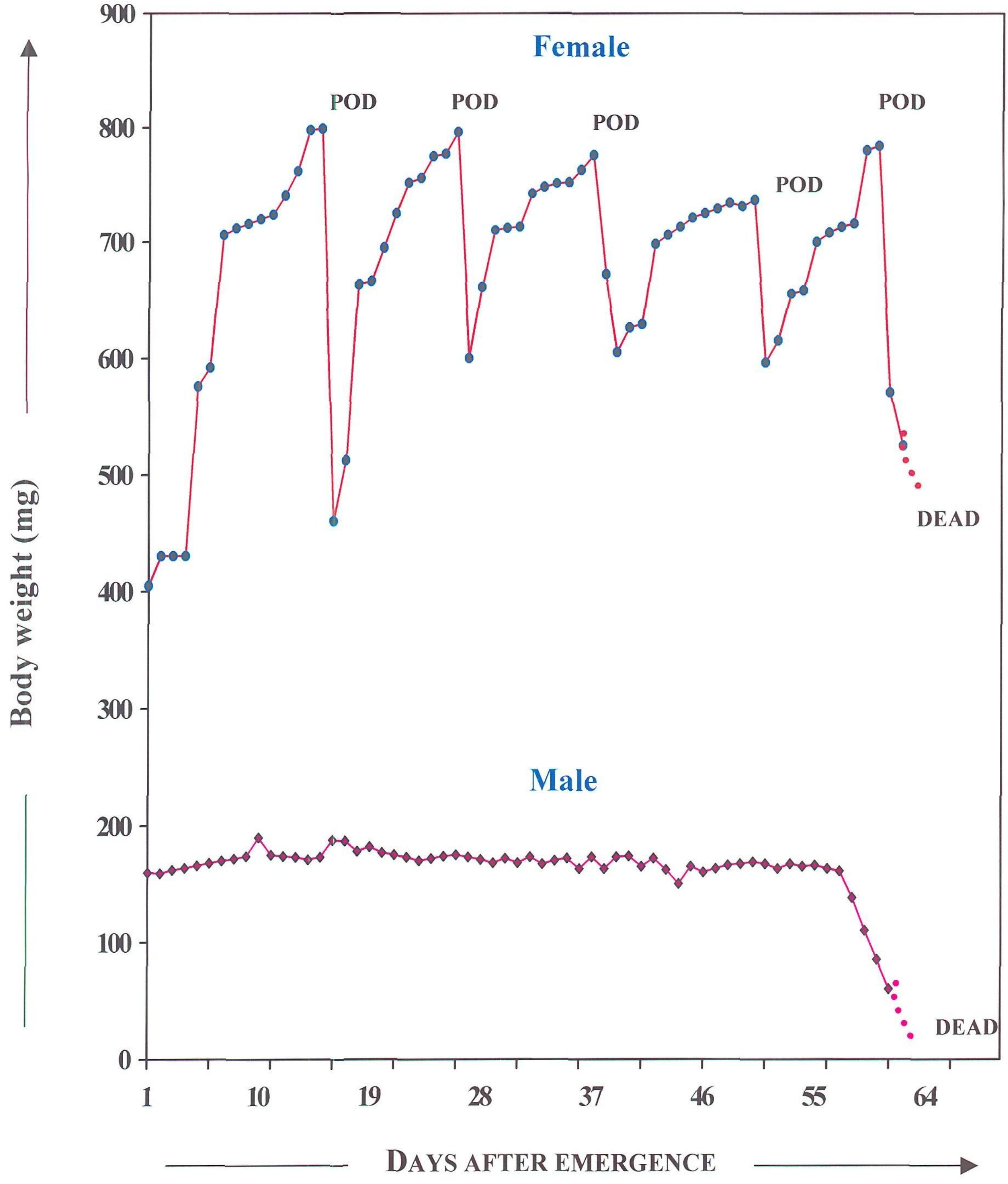


Fig.11. Daily variations in body weight of adults of *Acrida exaltata* Walk. during their life span

These body parts were selected for measurement as these have been considered important for behavioural studies by various workers in the field of acridology. Such body parts were measured in all stages of biology, starting from first instar hopper up to an adult in both sexes. The mean ratio of increase in size during development and growth were different in several body parts with variable magnitude. These observations are of applied nature as to study the morpho-ethological variations in a polymorphic acridid species. The measurements are given Table 6, 7 with all calculations and are self explanatory. It is to be noted that the mean rate of increase in case of males was highest in the length of middle femur (1.30) and lowest in the maximum width of head (1.13), while in case of females it was highest in the height of pronotum (1.40) and lowest in the vertical diameter of eye (1.18). The rate of increase instar-wise up to the adult, in all body parts, gives an overall picture of changes in this species which is basically a solitary, non - gregarious but showing occasional aggressive and swarm forming behaviour. These measurements are important with respect to possible polymorphic behaviour of this grasshopper.

The development of tegmina and wings in acridoids has already been considered as a special feature for distinguishing between hopper instars. In the first instar hopper, the lower posterior angles of the mesonotum and the metanotum do not show

Table: 6. Measurements (mm) of body parts of hoppers of *Acrida exaltata* Walk. and ratio of increase in various instars.

(10 REPLICATES)

MALES

Indices	Symbols	Instars							Ratio of increase						
		I	II	III	IV	V	VI	Adult	II/I	III/II	IV/III	V/IV	VI/V	Ad/VI	Mean Ratio
Length of body	L	8.43–9.87 (8.96±0.16)	10.01–12.23 (11.38±0.23)	14.46–18.35 (16.37±0.40)	18.35–21.47 (20.41±0.23)	24.36–27.36 (25.69±0.37)	23.91–35.26 (29.27±1.19)	26.67–37.98 (31.00±1.02)	1.27	1.44	1.25	1.26	1.14	1.06	1.24
Length of pronotum	P	1.01–1.22 (1.11±0.03)	1.33–1.55 (1.41±0.02)	1.78–2.00 (1.85±0.03)	2.33–2.78 (2.55±0.02)	3.56–4.22 (3.81±0.07)	4.00–4.56 (4.24±0.07)	4.82–5.18 (4.94±0.17)	1.27	1.31	1.38	1.49	1.11	1.16	1.29
Height of pronotum	H	0.64 – 0.80 (0.70±0.02)	0.77 – 0.89 (0.82±0.02)	0.96 – 1.33 (1.06±0.04)	1.33 – 1.55 (1.40±0.02)	1.44 – 1.89 (1.69±0.15)	2.00 – 2.22 (2.11±0.09)	2.21 – 2.82 (2.68±0.03)	1.17	1.29	1.32	1.21	1.25	1.27	1.25
Length of sternum	St	1.54 – 1.65 (1.59±0.01)	1.78 – 2.11 (1.91±0.04)	2.22 – 2.89 (2.62±0.07)	3.00–3.33 (3.18±0.04)	3.56–3.67 (3.60±0.02)	4.00–4.45 (4.25±0.08)	4.41–5.24 (5.05±0.09)	1.20	1.37	1.21	1.13	1.18	1.19	1.21
Length of anterior femur	AF	1.06 – 1.22 (1.13±0.02)	1.22 – 1.54 (1.35±0.03)	1.54 1.89 (1.73±0.04)	2.00 – 2.33 (2.13±0.03)	2.89 – 3.33 (2.94±0.06)	2.78 – 4.00 (3.39±0.12)	3.29 – 4.33 (3.76±0.08)	1.19	1.28	1.23	1.38	1.15	1.11	1.22
Length of middle femur	MF	1.17 – 1.38 (1.27±0.03)	1.44 – 1.76 (1.59±0.03)	1.92 – 2.24 (2.07±0.03)	2.44 – 2.67 (2.57±0.03)	3.56 4.00 (3.78±0.05)	3.67 – 4.67 (4.05±0.09)	4.51 – 6.36 (6.06±0.03)	1.25	1.30	1.24	1.47	1.07	1.50	1.30
Length of hind femur	F	4.32 – 4.91 (4.71±0.07)	5.11 – 6.40 (5.50±0.13)	5.98 – 7.84 (6.97±0.16)	8.00 – 10.01 (9.47±0.13)	10.01 – 13.35 (11.67±0.41)	12.01 – 13.90 (12.94±0.21)	13.60 – 19.06 (18.79±0.11)	1.17	1.27	1.36	1.23	1.11	1.45	1.26
Width of hind femur	f	0.42 – 0.53 (0.46±0.02)	0.53 – 0.55 (0.54±0.01)	0.66 0.69 (0.67±0.01)	0.77 – 0.89 (0.80±0.01)	0.89 – 1.22 (1.05±0.04)	1.00 – 1.33 (1.13±0.04)	1.10 – 1.38 (1.29±0.02)	1.17	1.24	1.19	1.31	1.08	1.14	1.19
Width of vertex between eyes	V	0.26 – 0.36 (0.32±0.01)	0.42 – 0.44 (0.43±0.01)	0.53 – 0.58 (0.55±0.01)	0.66 – 0.77 (0.69±0.01)	0.77 – 0.89 (0.80±0.02)	0.77 - 1.00 (0.89±0.03)	0.82 - 1.08 (0.96±0.01)	1.34	1.28	1.24	1.18	1.11	1.08	1.20
Vertical diameter of eye	O	0.89 – 1.17 (1.03±0.03)	1.11 – 1.38 (1.18±0.04)	1.44 – 1.55 (1.51±0.02)	1.66 – 1.89 (1.57±0.04)	1.89 – 2.22 (2.05±0.05)	2.00 – 2.44 (2.12±0.05)	2.33 – 2.54 (2.50±0.02)	1.15	1.28	1.04	1.31	1.03	1.19	1.17
Horizontal diameter of eye	Oh	0.42 – 0.48 (0.46±0.01)	0.53 – 0.55 (0.53±0.01)	0.58 – 0.69 (0.66±0.01)	0.66 – 0.77 (0.69±0.01)	0.89 – 1.00 (0.97±0.01)	0.89 – 1.11 (1.04±0.03)	1.06 – 1.23 (1.18±0.02)	1.15	1.25	1.05	1.41	1.07	1.13	1.18
Max. width of head	C	1.06 – 1.17 (1.14±0.01)	1.21 – 1.22 (1.22±0.01)	1.33 – 1.55 (1.45±0.03)	1.66 – 1.89 (1.75±0.01)	2.00 – 2.40 (2.07±0.04)	2.11 – 2.40 (2.15±0.03)	2.26 – 2.51 (2.38±0.01)	1.07	1.19	1.21	1.18	1.04	1.11	1.13
Length of antenna	A	2.34 – 2.61 (2.50±0.03)	2.89 – 3.33 (3.14±0.05)	4.00 – 4.33 (4.18±0.05)	4.40 - 5.56 (5.06±0.05)	6.11 - 7.78 (6.59±0.10)	7.23 – 9.67 (8.05±0.26)	9.31 - 11.00 (10.06±0.04)	1.26	1.33	1.21	1.30	1.22	1.25	1.26

Table: 7. Measurements (mm) of body parts of hoppers of *Acrida exaltata* Walk. and ratio of increase in various instars.

(10 REPLICATES)

FEMALES

Indices	Symbols	Instars							Ratio of increase						
		I	II	III	IV	V	VI	Adult	II/I	III/II	IV/III	V/IV	VI/V	Ad/VI	Mean Ratio
Length of body	L	8.54–9.87 (9.34±0.13)	11.21–12.70 (12.15±0.12)	14.46–18.46 (16.77±0.21)	21.13–23.36 (22.44±0.24)	25.03–27.81 (26.86±0.32)	28.81–35.60 (33.02±0.71)	40.10–52.23 (48.73±0.62)	1.30	1.38	1.34	1.20	1.23	1.26	1.29
Length of pronotum	P	1.01–1.22 (1.13±0.02)	1.12–1.44 (1.40±0.04)	1.78–2.22 (2.03±0.05)	2.55–2.89 (2.72±0.04)	2.78–4.33 (3.68±0.20)	5.00–6.11 (5.44±0.11)	6.11–8.02 (7.96±0.18)	1.24	1.45	1.34	1.35	1.48	1.35	1.37
Height of pronotum	H	0.75 – 0.85 (0.79±0.02)	0.74 – 0.89 (0.85±0.02)	1.01 – 1.22 (1.14±0.02)	1.33 – 1.66 (1.53±0.03)	1.55 – 2.33 (2.09±0.09)	2.67 – 3.00 (2.83±0.04)	2.98 – 4.44 (4.37±0.03)	1.08	1.34	1.34	1.37	1.35	1.91	1.40
Length of sternum	St	1.60 – 1.65 (1.61±0.01)	1.66 – 1.78 (1.75±0.02)	2.55 – 2.89 (2.74±0.03)	3.00–3.67 (3.35±0.07)	4.22–5.00 (4.56±0.07)	5.22–6.45 (5.64±0.12)	6.50–12.01 (11.64±0.22)	1.09	1.57	1.22	1.36	1.24	1.88	1.39
Length of anterior femur	AF	1.06 – 1.22 (1.18±0.02)	1.28 – 1.55 (1.38±0.03)	1.65 – 2.00 (1.81±0.05)	2.11 – 2.67 (2.38±0.07)	3.00 – 3.67 (3.34±0.08)	3.67 – 4.45 (3.90±0.07)	4.98 – 6.72 (6.67±0.08)	1.17	1.31	1.31	1.40	1.17	1.48	1.31
Length of middle femur	MF	1.17 – 1.38 (1.28±0.02)	1.49 – 1.78 (1.63±0.03)	2.00 – 2.22 (2.12±0.03)	2.55 – 3.22 (2.82±0.08)	3.33 – 4.45 (4.10±0.12)	4.67 – 5.56 (4.93±0.09)	6.68 – 9.45 (9.33±0.09)	1.27	1.30	1.33	1.45	1.20	1.68	1.37
Length of hind femur	F	4.00 – 4.91 (4.69±0.09)	4.85 – 6.19 (5.75±0.13)	6.99 – 8.90 (8.02±0.20)	9.79 – 11.12 (10.46±0.19)	11.68 – 14.68 (13.61±0.34)	16.13 – 17.80 (16.72±0.20)	24.62 – 32.21 (29.86±0.82)	1.23	1.39	1.30	1.30	1.23	1.55	1.33
Width of hind femur	f	0.42 – 0.53 (0.47±0.01)	0.53 – 0.58 (0.55±0.01)	0.66 – 0.77 (0.67±0.01)	0.89 – 1.11 (0.96±0.02)	1.11 – 1.33 (1.20±0.02)	1.33 – 1.66 (1.49±0.04)	1.71 – 2.40 (2.34±0.13)	1.17	1.22	1.43	1.25	1.24	1.42	1.29
Width of vertex between eyes	V	0.32 – 0.37 (0.32±0.01)	0.42 – 0.44 (0.43±0.01)	0.53 – 0.55 (0.54±0.01)	0.64 – 0.66 (0.65±0.01)	0.74 – 0.77 (0.76±0.01)	0.80 – 0.89 (0.86±0.01)	0.98 – 1.11 (1.07±0.02)	1.34	1.26	1.20	1.17	1.13	1.16	1.21
Vertical diameter of eye	O	1.01 – 1.17 (1.10±0.02)	1.11 – 1.65 (1.25±0.05)	1.33 – 1.54 (1.41±0.02)	1.55 – 1.89 (1.70±0.04)	2.00 – 2.11 (2.05±0.02)	2.22 – 2.44 (2.33±0.03)	2.56 – 3.33 (3.11±0.06)	1.14	1.13	1.21	1.21	1.14	1.26	1.18
Horizontal diameter of eye	Oh	0.42 – 0.48 (0.45±0.01)	0.53 – 0.58 (0.53±0.01)	0.54– 0.69 (0.59±0.02)	0.77 – 0.89 (0.83±0.02)	1.00 – 1.06 (1.01±0.01)	1.06 – 1.11 (1.09±0.01)	1.81 – 2.12 (2.07±0.01)	1.18	1.11	1.41	1.22	1.08	1.66	1.28
Max. width of head	C	1.12 – 1.22 (1.20±0.01)	1.22 – 1.33 (1.24±0.01)	1.55 – 1.66 (1.64±0.01)	1.78 – 2.11 (1.92±0.04)	2.44 – 2.67 (2.52±0.03)	2.78 – 3.33 (3.08±0.06)	3.82 – 4.61 (4.56±0.05)	1.03	1.32	1.17	1.31	1.22	1.45	1.25
Length of antenna	A	2.45 – 2.56 (2.48±0.01)	2.89 – 3.33 (3.14±0.05)	3.89 – 5.00 (4.55±0.10)	5.56 – 6.23 (5.98±0.08)	6.67 – 8.90 (7.75±0.20)	8.90 – 9.67 (9.26±0.08)	11.01– 14.31 (14.01±0.13)	1.28	1.45	1.31	1.3	1.19	1.51	1.34

any differentiation but in the second instar they become somewhat extended and punctured, and in the subsequent instars they appear as rounded-triangular lobes, directed obliquely downward with distinct traces of longitudinal ridges, which are tracheae, later to become axillary vein; their number in the hind wings of *Acrida exaltata* increases at each moult. The striking change occurs in the alar rudiments in the second instar and both pairs of rudiments turned on their axes so that the outer surfaces become the inner and the rudiments of the tegmina (attached to the mesonotum become covered by those of the wings, both lying dorsally and directed obliquely upwards). The reversal of the alar rudiments thus divided the hopper instar into two distinct groups. The instar in which the reversal occurs, varies according to the total number of instars and may differ in two sexes of the same species. In case of *Acrida exaltata*, the instar pass through different number of instars in the two sexes. In this case, rudiments are lateral up to third instar and rudiments reversed in the fourth and fifth instars before becoming adult. This is in case of males (having five hopper instars), while in females rudiments remain lateral up to the fourth instar and rudiments reversed in fifth and sixth instars before becoming adult. The reversal of alar rudiments in male and female of this species having different numbers of instars is illustrated in Figs. 19, 20 and Table 8.

Table: 8. Hopper instars of *Acrida exaltata* Walk. in which the reversal of alar rudiments occurs.

(L, rudiments lateral, R, rudiments reversed, Ad, adult)

Sex	Instars								
	I	II	III	IV	V	VI	VII	VIII	Ad
Males having 5 instars	L	L	L	R	R	Ad			
Males having 6 instars	L	L	L	L	R	R	Ad		
Females having 6 instars	L	L	L	L	R	R	Ad		
Females having 7 instars	L	L	L	L	L	R	R	Ad	
Females having 8 instars	L	L	L	L	L	L	R	R	Ad

On the basis of hopper instars in which the reversal of alar rudiments occurs differently in the two sexes, which may be of significance in the male and female distinctive mature stages.

The sexual differentiation of the terminal abdominal segment and of the external genitalia in different instars, as well as in the two sexes, can be distinguished in hoppers without any difficulty. The changes in external genitalia during the development of *Acrida exaltata* are shown in Figs. 21, 22. The only noticeable change is found at the stage of final instar in two sexes. Female has eight instars in which both upper and lower valves are longer than paraprocts, while in case of male there are six instars, where subgenital plate is elongated–parabolic, much longer than paraprocts. Such descriptions and identification for hoppers are particularly needed for ecological studies in which it is essential to distinguish between species in mixed population from their instars. A comparative description on the changes of the terminal abdominal segments during the development in both sexes are as follows:

Instar	**Male**	**Female**
I	Subgenital plate semi–circular in shape and slightly excised at apex, covering only base of paraprocts.	Upper ovipositor valves short, triangular sub– acute, separated by a deep rectangular excision. Lower

		valves represented by a transverse fold (distinct only towards end of the instar) at bases of upper valves.
II	Subgenital plate semi-circularly excised at apex with short obtuse lobes.	Upper ovipositor valves small, acute, separated by a deep and acute excision. Lower valves represented by a transverse fold with slight projection in the middle.
III	Subgenital plate narrowed to apex, which has a shallow excision and reaches middle of paraprocts.	Upper ovipositor valves longer, acute, separated by deep and acute excision. Lower valves triangular, separated by narrow excision.
IV	Subgenital plate with narrowly parabolic apex reaching almost to apex of paraprocts.	Upper valves longer, separated by narrow excision. Lower valves longer than that of the III instar
V	Subgenital plate elongate-parabolic, much longer than paraprocts.	Left and right ovipositor valves separated along the middle line. Upper valve

		shorter than paraprocts.
VI	Subgenital plate much elongate parabolic pointed at the apex.	Lower valves almost as long as upper.
VII	----	Upper valves reaching at the apex of the paraprocts.
VIII	----	Both upper and lower valves longer than paraprocts.
Adult	Aedeagus is formed.	Lower and upper ovipositor valves sclerotised. Ovipositor fully formed.

The moulting from one hopper instar to the next is essentially a biological repetition. The hopper climbs a plant or twig and hangs head downward thus utilizing the gravity in the process but it was notable that impartial moultings do occur, when there is over–crowding in the cages. Such impartial moultings lead to various deformities, which are manifested in various morphological changes but having no adverse effect on the reproductive potential. This is a new observation hitherto unknown.

The variation in the number of hopper instars between species or in a single species taking sexes into account, have already been reported by various acridologists. The sub–family Acridinae shows variation in the number of instars in both sexes and thus the duration of hopper development period of this species at 35±1 °C and 70±5 % R.H., has been recorded (Table 9, 10), which shows significantly different hopper development period in both sexes if the instar numbers are changed. It is to be noted that if the average total hopper duration reduces or increases as in case of this species it indicates the number of instars. In this species male cycle with five instar hoppers having 33.67±0.64 days average hopper duration, while female cycle with six instar hoppers having 42.63±0.75 days average hopper duration. This confirms that the number of instars are directly linked with hopper duration. This observation is also a new one.

Table: 9. *Acrida exaltata* Walk. : Period taken by isolated hoppers for development reared at 35±1 °C on grass, *Cynodon dactylon* Pers. leaves.

(30 REPLICATES)

AVERAGE HOPPER DURATION (DAYS)	MALES WITH 5 INSTARS	MALES WITH 6 INSTARS	FEMALES WITH 6 INSTARS	FEMALES WITH 7 INSTARS	FEMALES WITH 8 INSTARS
I INSTAR	5–9 (6.60±0.19)	6–9 (7.67±0.81)	5–8 (6.27±0.20)	5–9 (6.93±0.31)	8–12 (10.17±0.24)
II INSTAR	5–9 (6.60±0.21)	4–9 (6.20±0.26)	4–13 (7.73±0.48)	5–9 (6.63±0.21)	10–29 (17.23±0.97)
III INSTAR	5–9 (6.63±0.26)	5–8 (6.53±0.20)	4–10 (6.27±0.27)	5–9 (6.80±0.20)	8–14 (11.10±0.36)
IV INSTAR	5–9 (6.83±0.23)	5–9 (6.97±0.22)	5–9 (6.83±0.24)	5–14 (8.07±0.43)	5–11 (8.63±0.34)
V INSTAR	6–12 (8.23±0.27)	6–9 (7.23±0.21)	6–13 (7.50±0.33)	4–10 (7.17±0.35)	5–9 (6.630±0.44)
VI INSTAR	–	7–14 (9.10±0.28)	6–12 (9.07±0.30)	6–11 (8.30±0.24)	5–7 (5.87±0.15)
VII INSTAR	–	–	–	6–14 (9.17±0.40)	7–9 (7.83±0.14)
VIII INSTAR	–	–	–	–	8–12 (9.47±0.23)
AVERAGE TOTAL HOPPER DURATION (DAYS)	28–42 (33.67±0.64)	38–49 (43.53±0.53)	32–49 (42.63±0.75)	41–70 (55.83±1.29)	75–92 (83.33±0.63)
DEVELOPMENT OF HOPPERS/ DAY (%)	2.83–3.57 (3.00±0.06)	2.04–2.44 (2.29±0.03)	2.04–2.78 (2.36±0.04)	1.42–2.43 (1.82±0.04)	1.08–1.33 (1.20±0.01)

Mean ± S.E. is given in parentheses.

Table: 10. Summary of life – history at 35±1 °C. Hoppers and adults fed on grass, *Cynodon dactylon* Pers. leaves.

(10 REPLICATES)

LENGTH OF PERIODS (DAYS)	*Acrida exaltata* Walk.		*Phlaeoba infumata* Brunn.	
	MALE	FEMALE	MALE	FEMALE
Average total hopper duration	38 – 49 (43.53±0.53)	41 – 70 (55.83±1.29)	35 – 50 (46.13±1.36)	42 – 62 (55.87±1.47)
Pre–copulation period	8–14 (10.00±0.60)	8 – 16 (11.60±0.93)	9 – 16 (12.80±0.70)	10 – 18 (13.50±0.79)
Post–copulation period	–	8 – 15 (12.24±0.89)	–	10 – 16 (12.90±0.55)
Pre–oviposition period	–	16 – 39 (23.50±2.12)	–	20 – 26 (22.50±0.60)
Oviposition period	–	14 – 26 (18.90±1.47)	–	10 – 30 (21.90±1.84)
Post–oviposition period	–	1 – 17 (5.30±1.61)	–	2 – 42 (13.10±3.62)
Longevity of adults	16 – 55 (40.50±5.47)	42 – 62 (48.40±2.97)	50 – 80 (67.90±3.54)	60 – 90 (75.70±3.52)
Total life–span	55 – 85 (70.90±3.10)	80 – 135 (109.40±5.93)	65 – 135 (109.80±8.04)	90 – 150 (123.00±5.88)

Mean ± S.E. is given in parentheses.

Variation in the number of hopper instars:

Variation in hopper instar number within the species is of an ecological interest. These have been regarded as abnormalities, which is not true in view of the present observations. When the laboratory and field population were compared in terms of percentage of instar hoppers, it was found that the laboratory population in this species mostly consists of 80%, fifth instars, in males and, sixth instars, in females. On calculations the sixth instar was found ranging from 6–7 % and this could be attributed to two factors, namely control conditions and environmental conditions. This behaviour of the species for having an additional instar can also be attributed with their ecological adaptation to the rapid changing climatic condition and changes in preferred food availability.

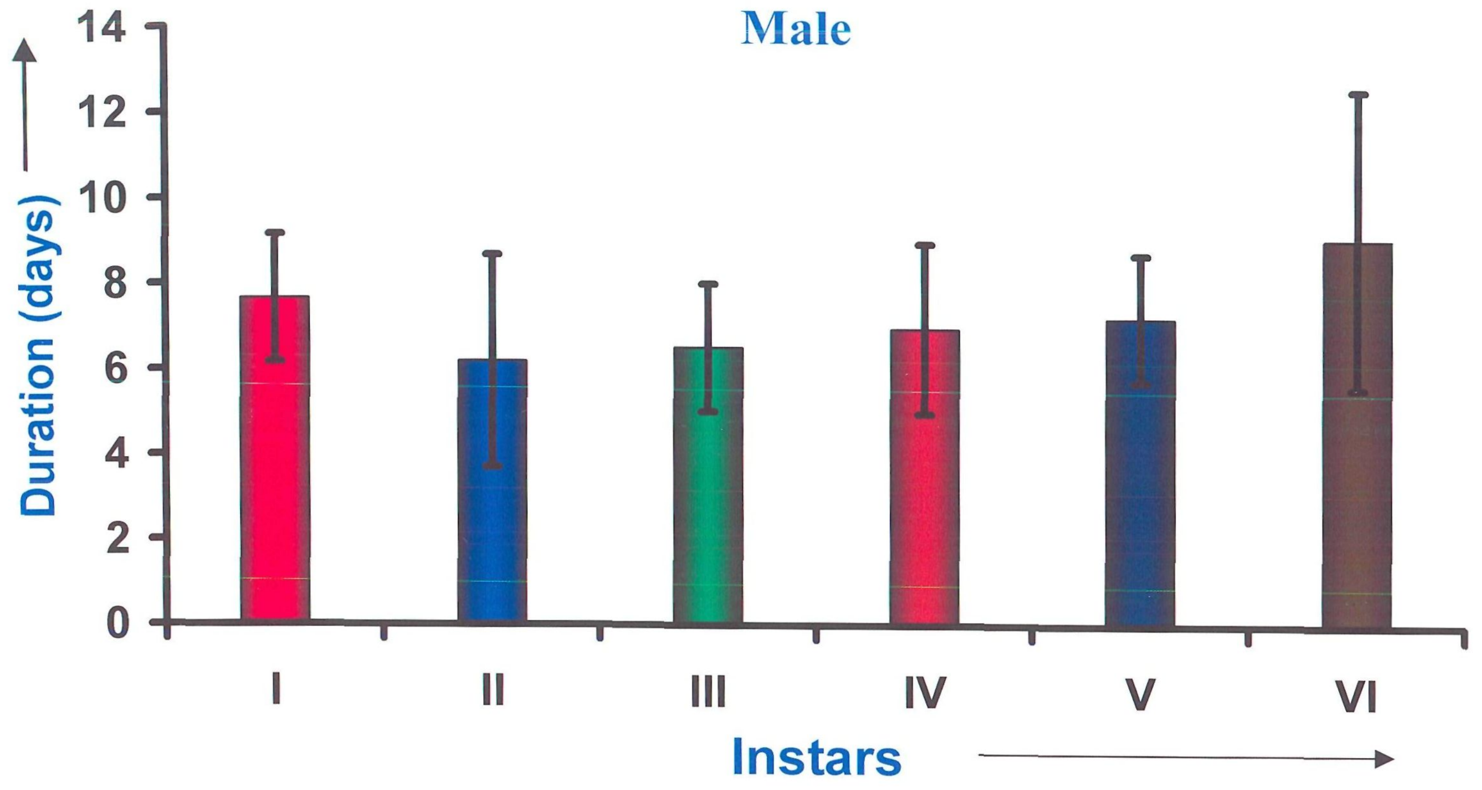


FIG.12. Nymphal duration and range variables of *Acrida exaltata* walk.

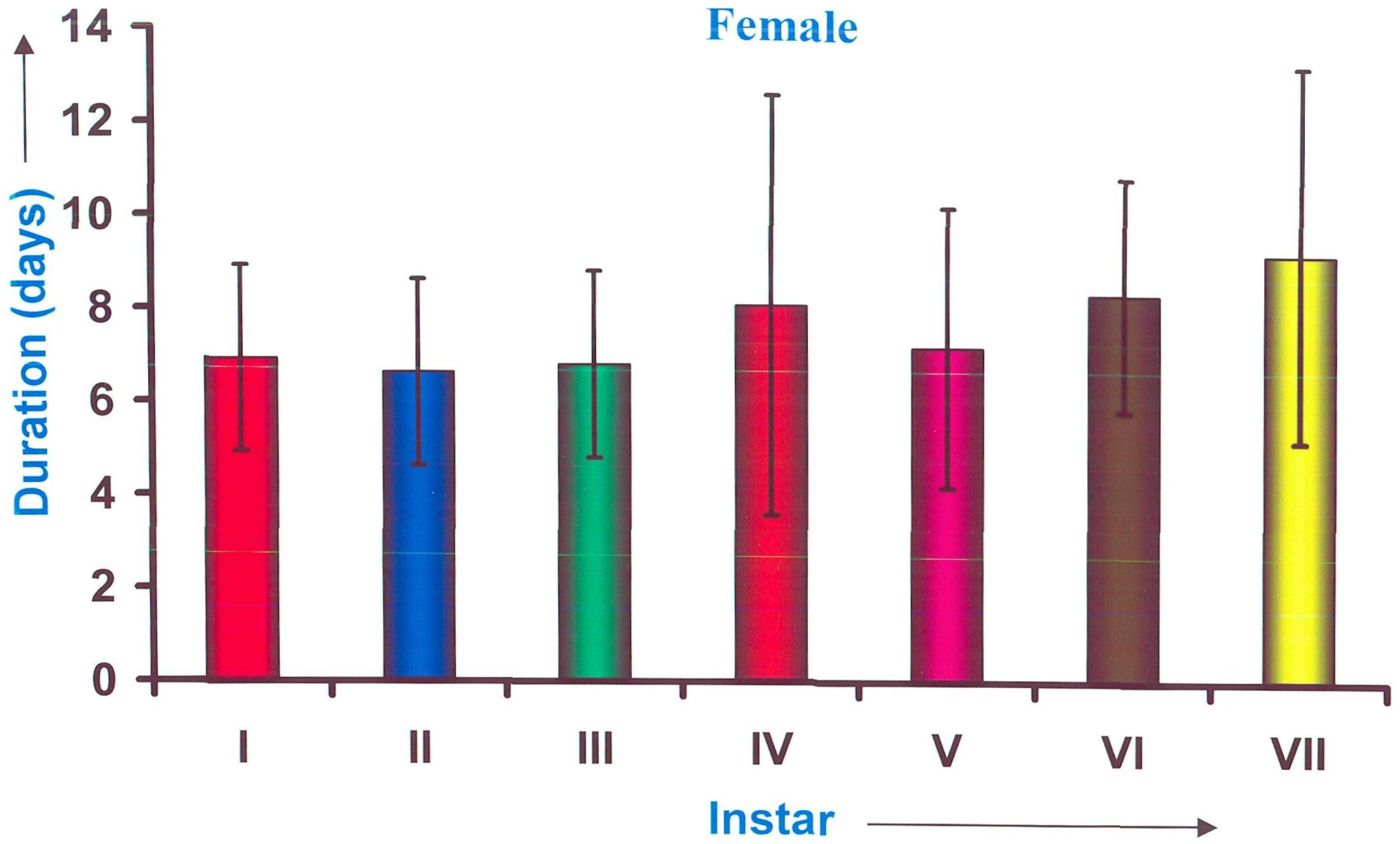


FIG.13. Nymphal duration and range variables of *Acrida exaltata* walk.

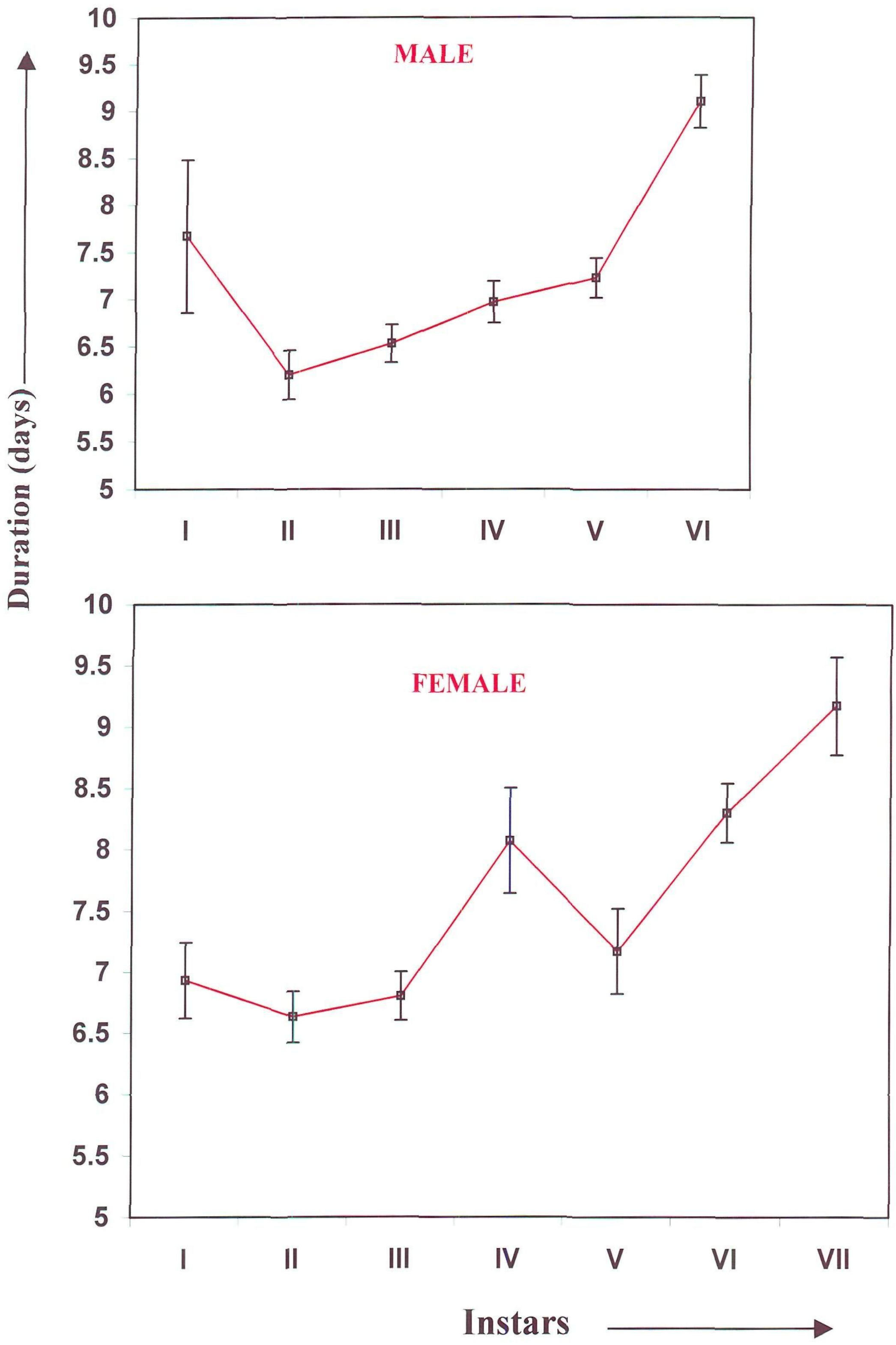


Fig. 14. Nymphal duration of *Acrida exaltata* Walk.

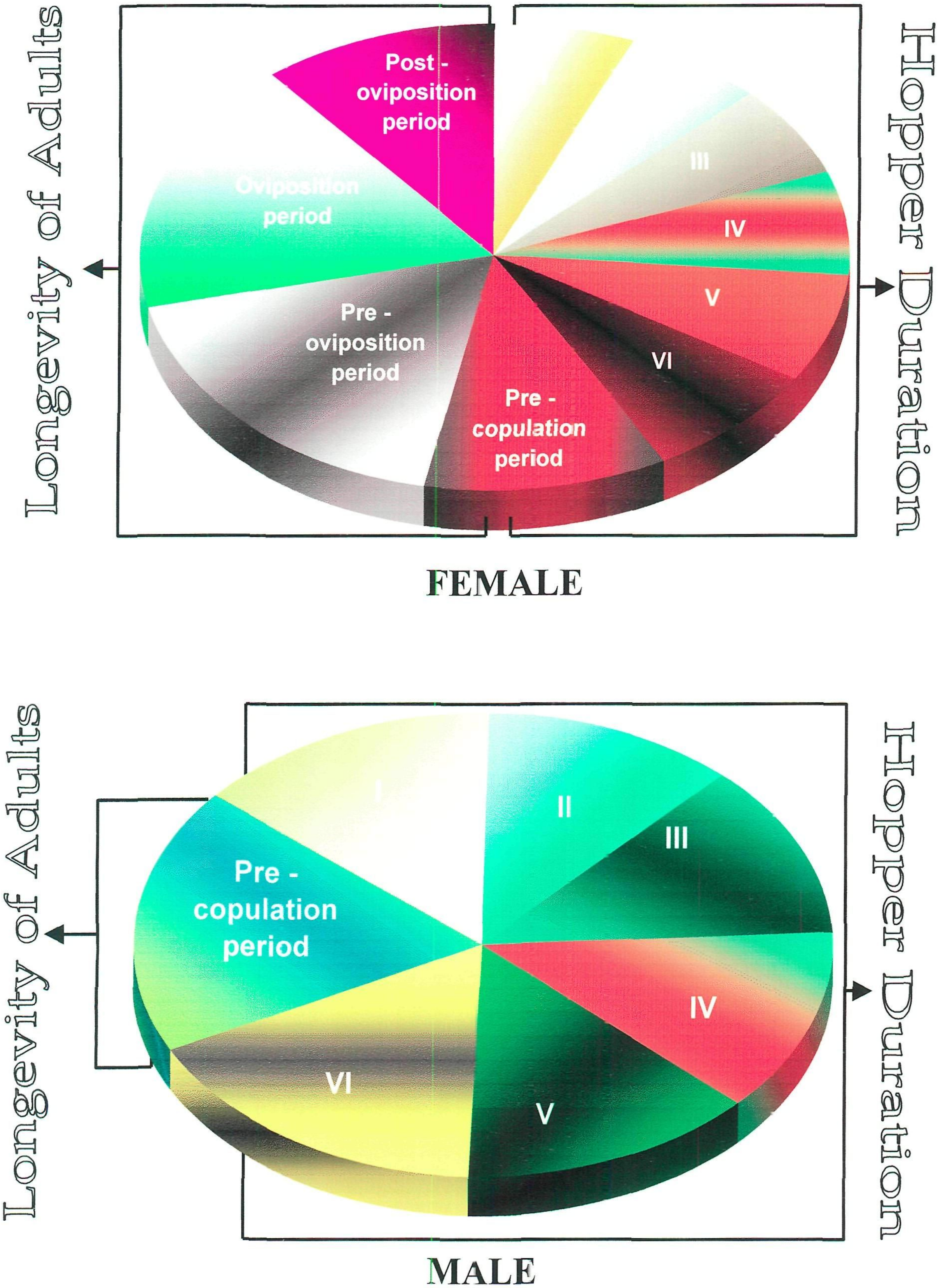


Fig: 15. Diagrammatic presentation of biological indices of *Acrida exaltata* Walk.

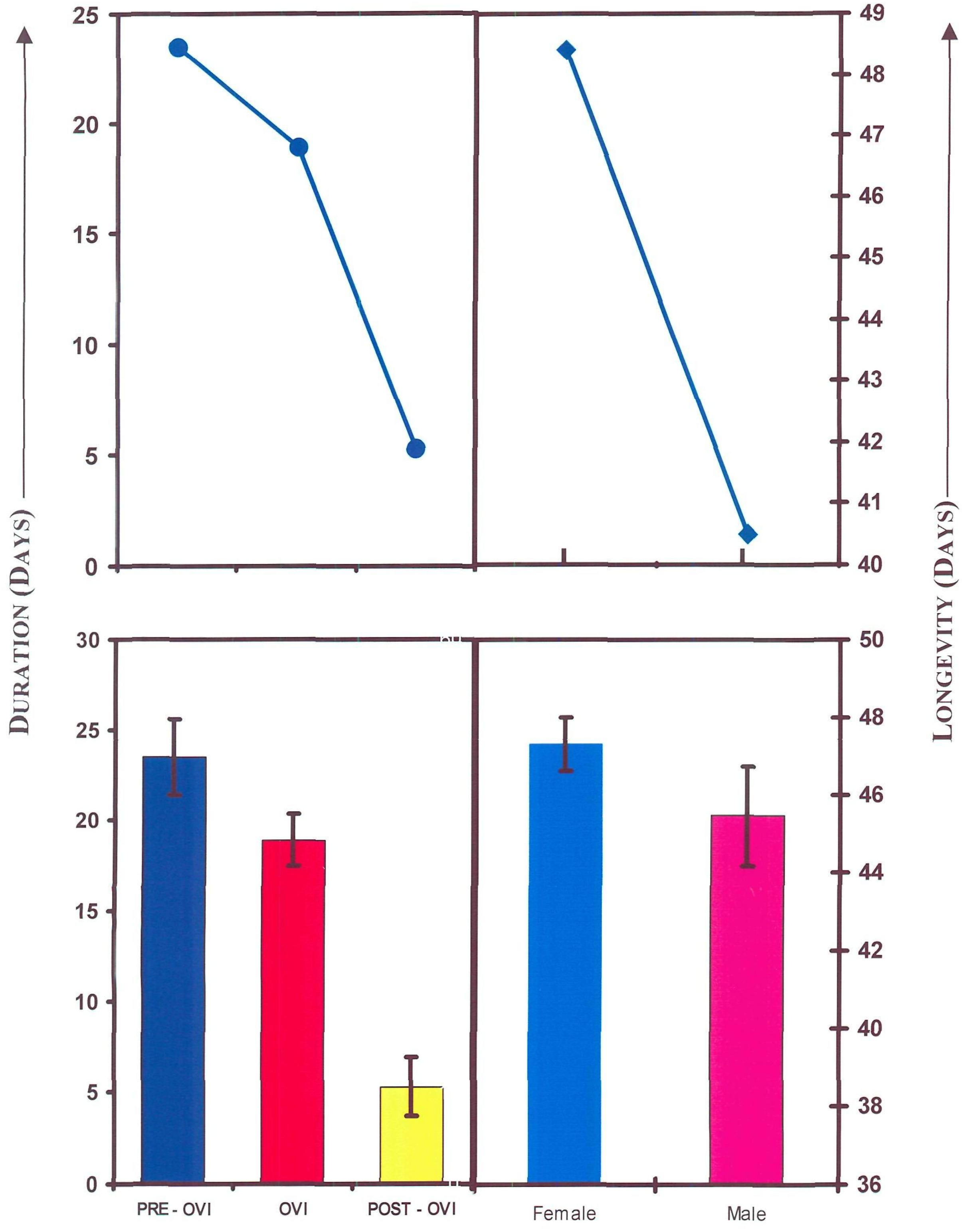


Fig.16. Pre–oviposition, Oviposition and Post–oviposition periods and longevity of adults of *Acrida exaltata* Walk.

DESCRIPTION OF HOPPER INSTARS:

First instar hopper:

The freshly hatched nymphs are yellowish brown or pale green in colour with brownish dots dorsally, paler ventrally; head is pale brown bearing brown markings; two anterior pairs of legs, pale with brownish markings, hind pair is pinkish. Wing rudiments indistinct. Average body length of males 8.96 mm, females 9.34 mm. Antennae with 8 segments (Figs 24, 32).

Second instar hopper:

Greenish–brownish dorsally, paler ventrally, dim dots on the body. Head brown with few blackish dots. Hind legs brown with prominent black dots and stripes. Wing pads present. Sexes more distinct. Ovipositor valves of female present. Average body length of males 11.38 mm, females 12.15 mm. Antennae with 8–10 segments (Figs. 25, 33).

Third instar hopper:

Similar to second instar except the tips of antennae and tibae are darker. Wing pads more distinct. Ovipositor valves very clear. Average body length of males 16.37 mm, females 16.77 mm. Antennae with 10–12 segments (Figs. 26, 34).

Fourth instar hopper:

General colouration dull brown with small black dots and stripes dorsally, pale ventrally; wing buds reversed in males. Average body length of males 20.41 mm, females 22.44 mm. Antennae with 12 segments (Figs. 27, 35).

Fifth instar hopper:

General colouration brownish, eyes, antennae, head and thorax darker than in previous instar. Wing buds reversed in females. Average body length of males 25.69 mm, females 24.95 mm. Antennae with 12–14 segments. Males becoming adult following the moult at the end of this instar (Figs. 28, 36).

Sixth instar hopper:

General colouration dull, dark green or brownish dorsally, light yellowish brown ventrally. Ovipositor valves well developed. Average body length is 29.27 mm in male and 33.02 in females. Antennal segments 14 – 15. (Figs. 29, 37).

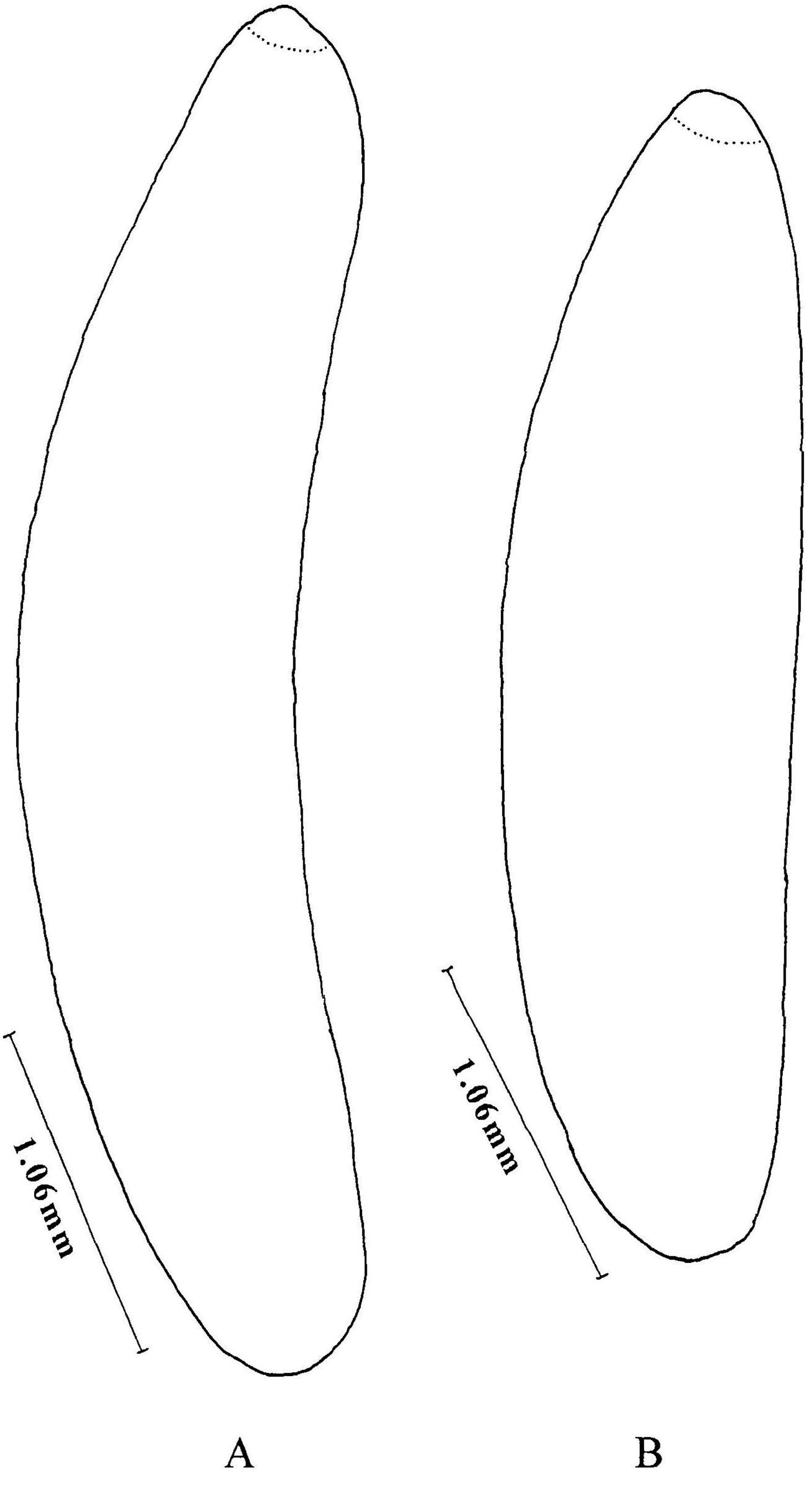
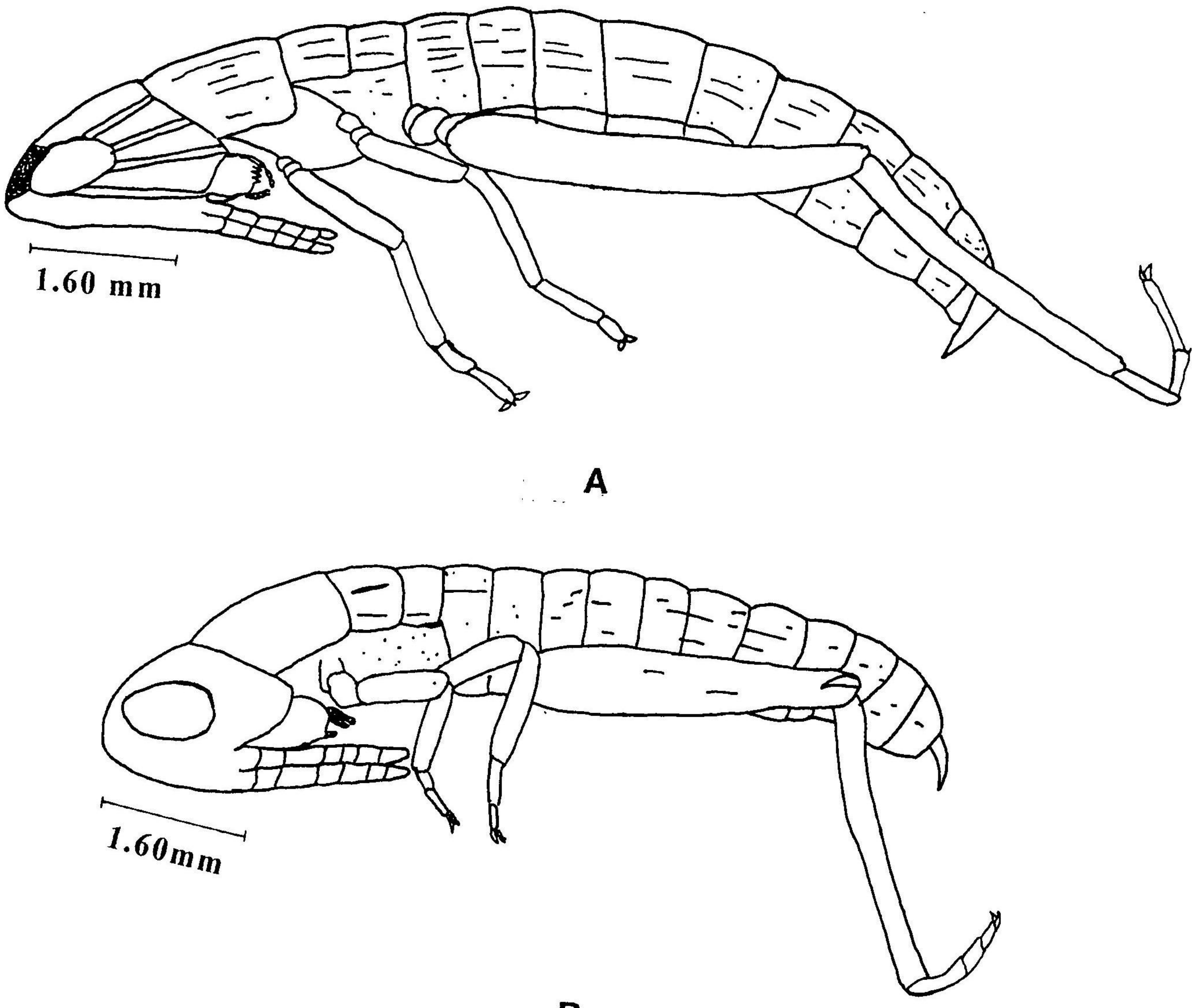


FIG.17. EGGS

A – *Acrida exaltata* Walk.

B – *Phlaeoba infumata* Brunn.



A B

FIG.18. HATCHLINGS

A – *Acrida exaltata* Walk.

B – *Phlaeoba infumata* Brunn.

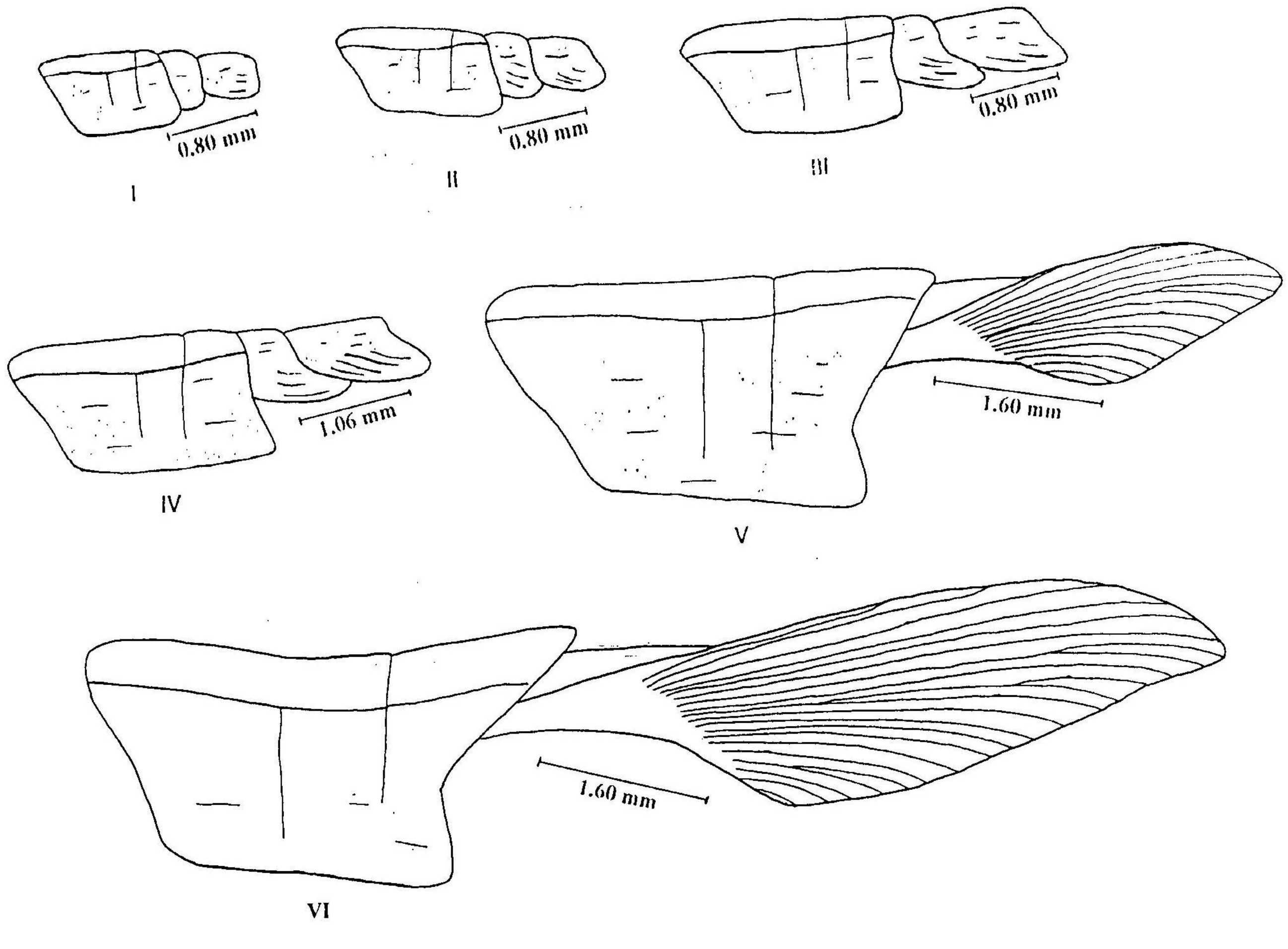


FIG.19. ***Acrida exaltata*** **Walk., growth of wing rudiments in male**

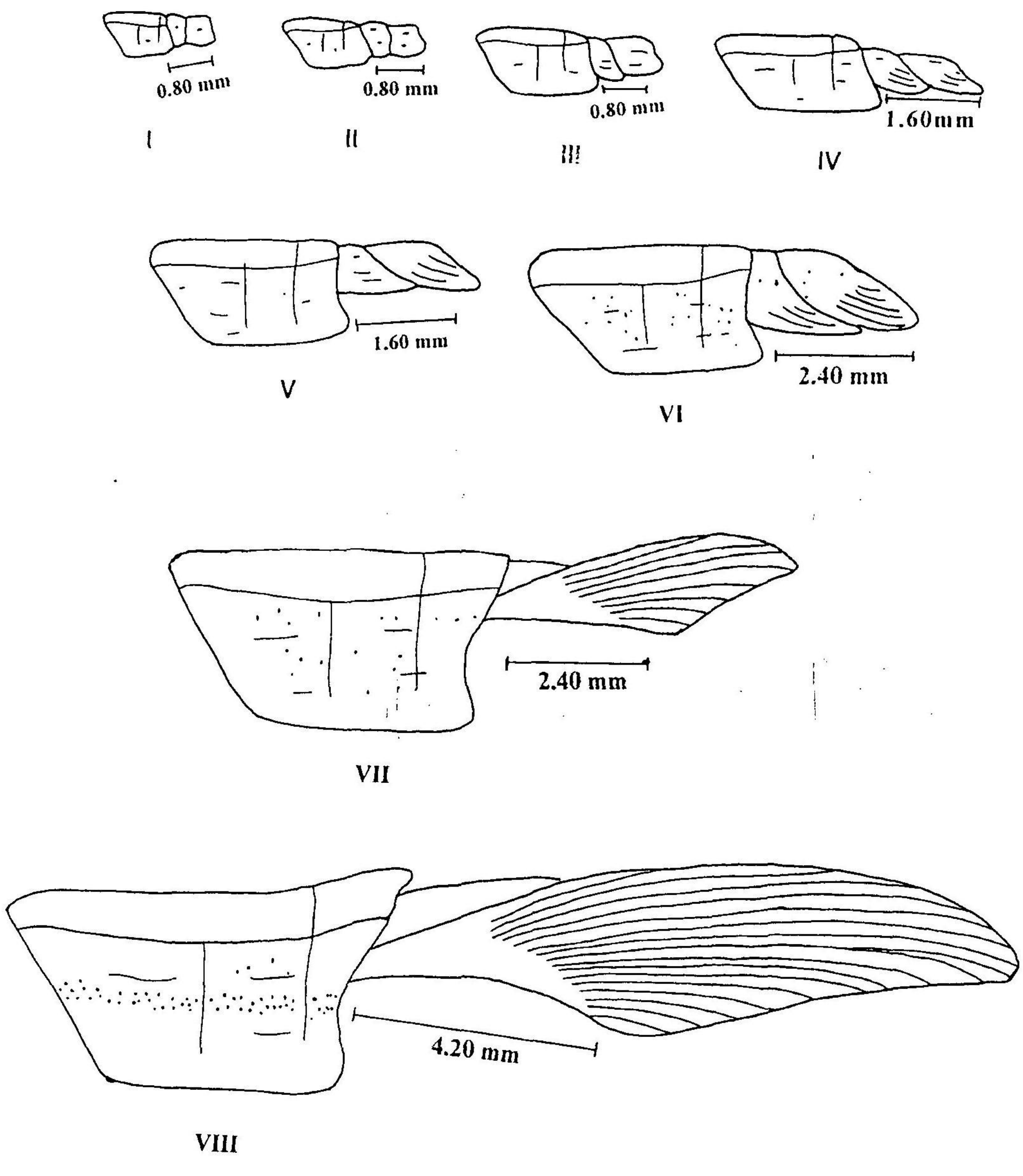


FIG.20. ***Acrida exaltata*** **Walk., growth of wing rudiments in female**

SG, SUBGENITAL PLATE
P, PARAPROCT

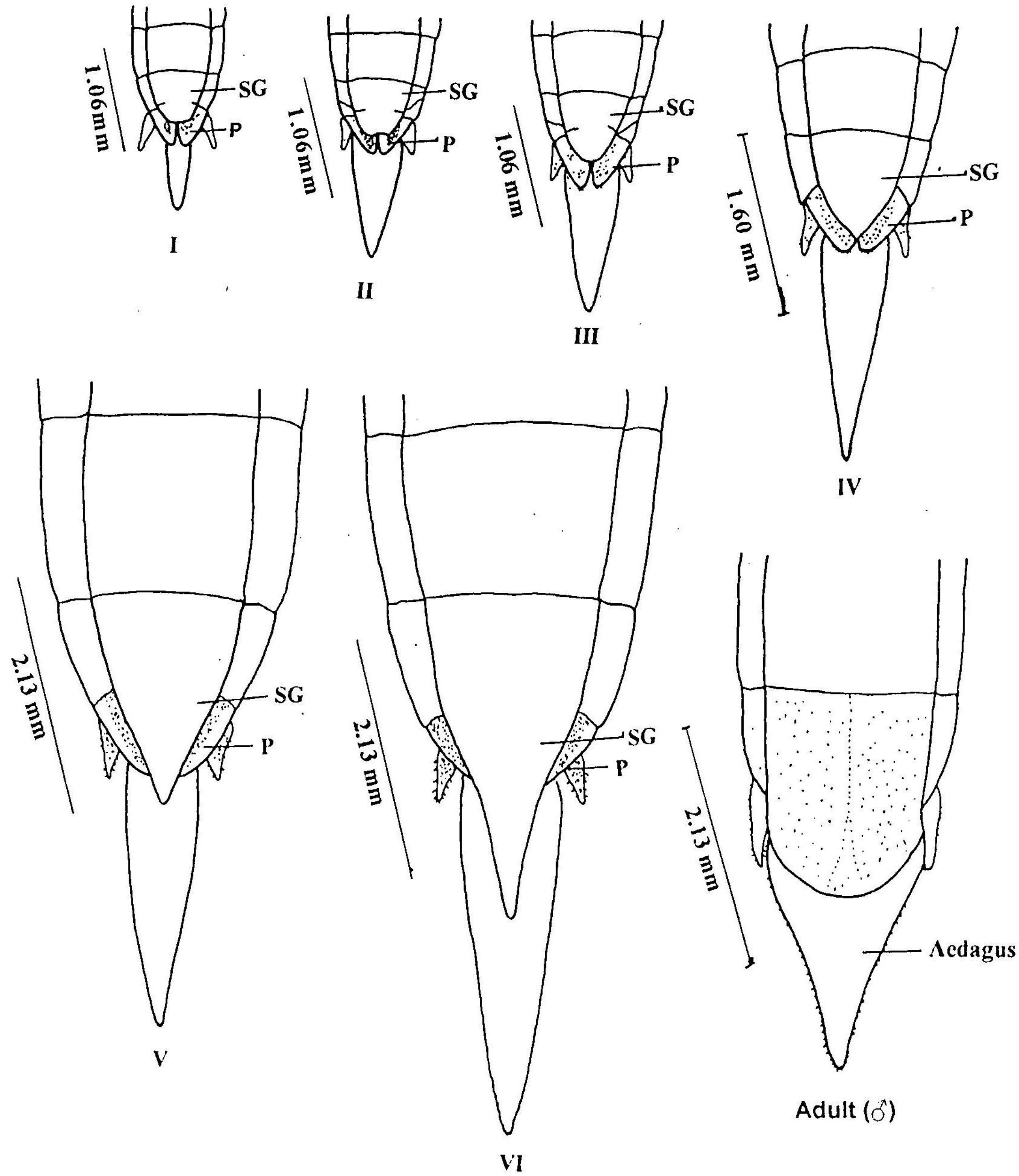


FIG.21. *Acrida exaltata* Walk., growth of external genitalia in male

LV, LOWER OVIPOSITOR VALVE
UV, UPPER OVIPOSITOR VALVE
P, PARAPROCT

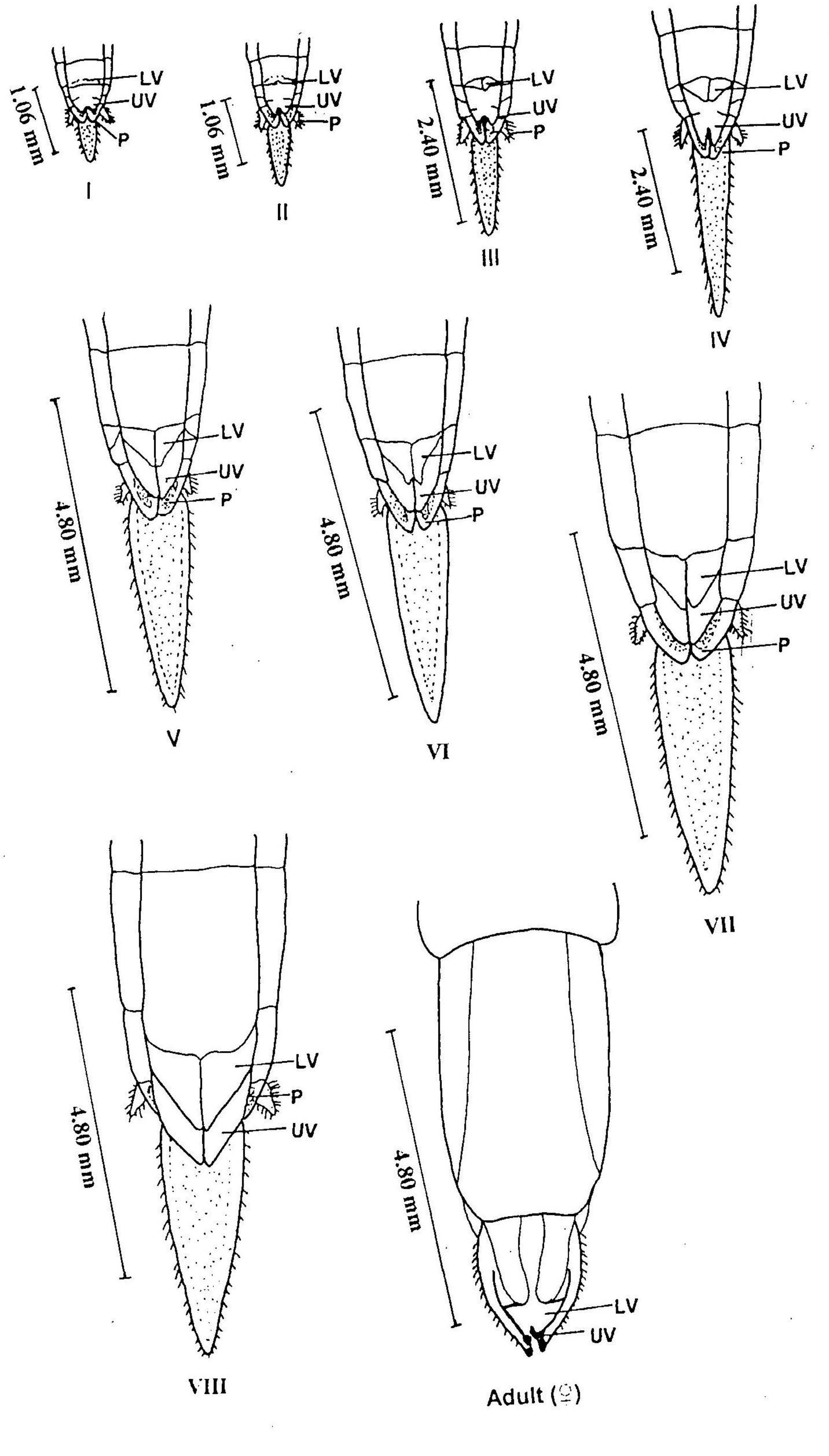


FIG.22. *Acrida exaltata* Walk., growth of external genitalia in female

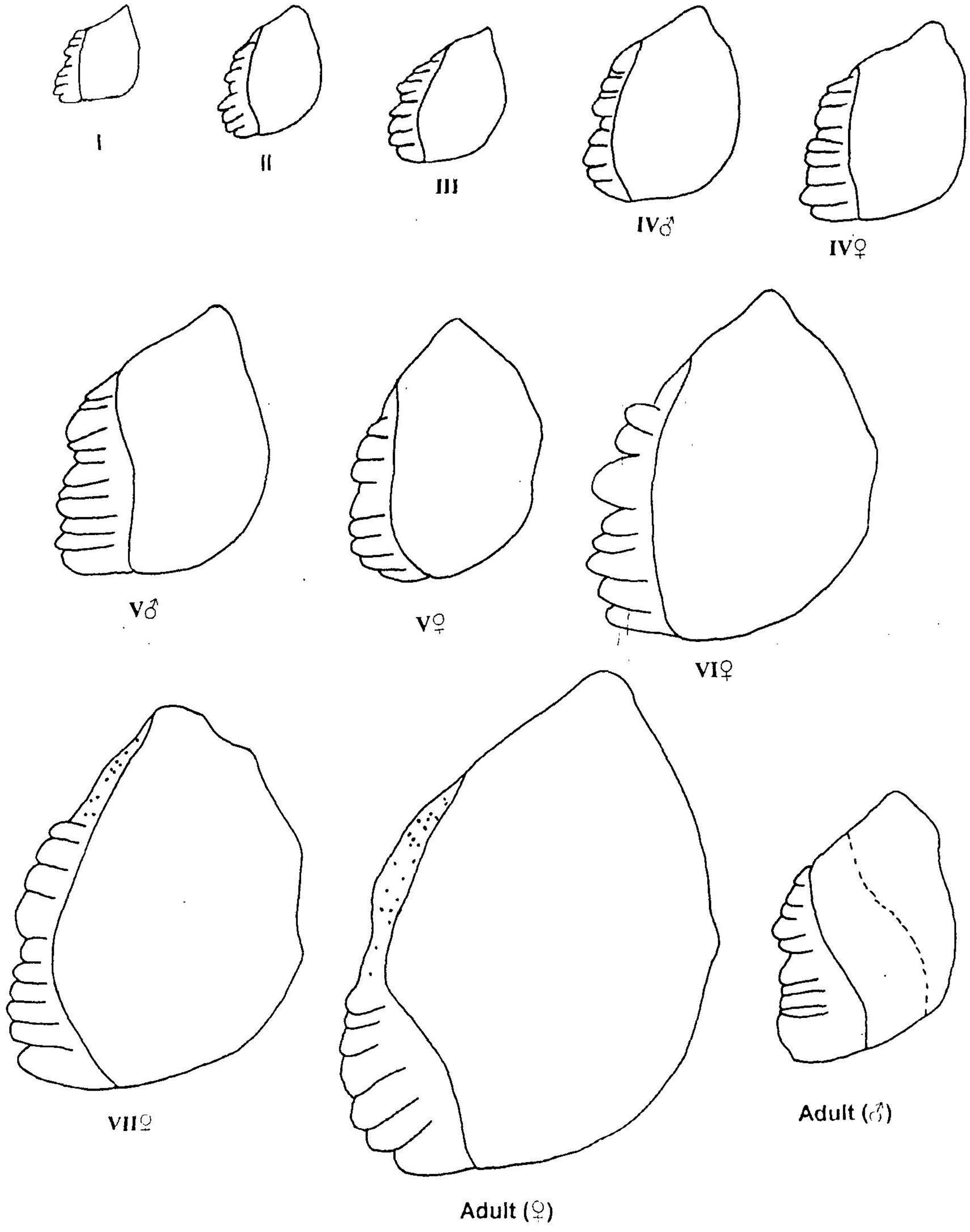


FIG.23. *Acrida exaltata* **Walk., development of mandibular teeth**

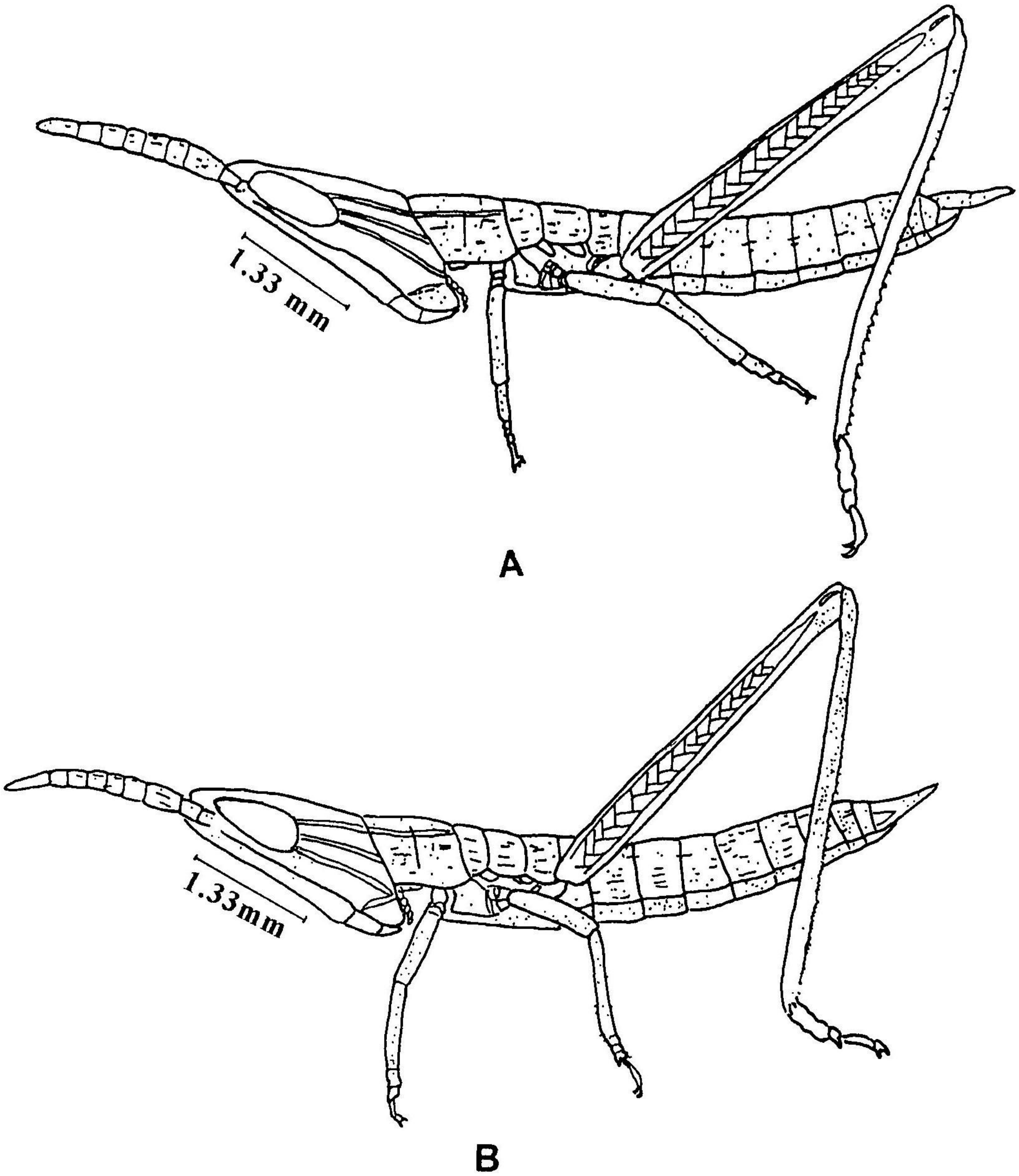
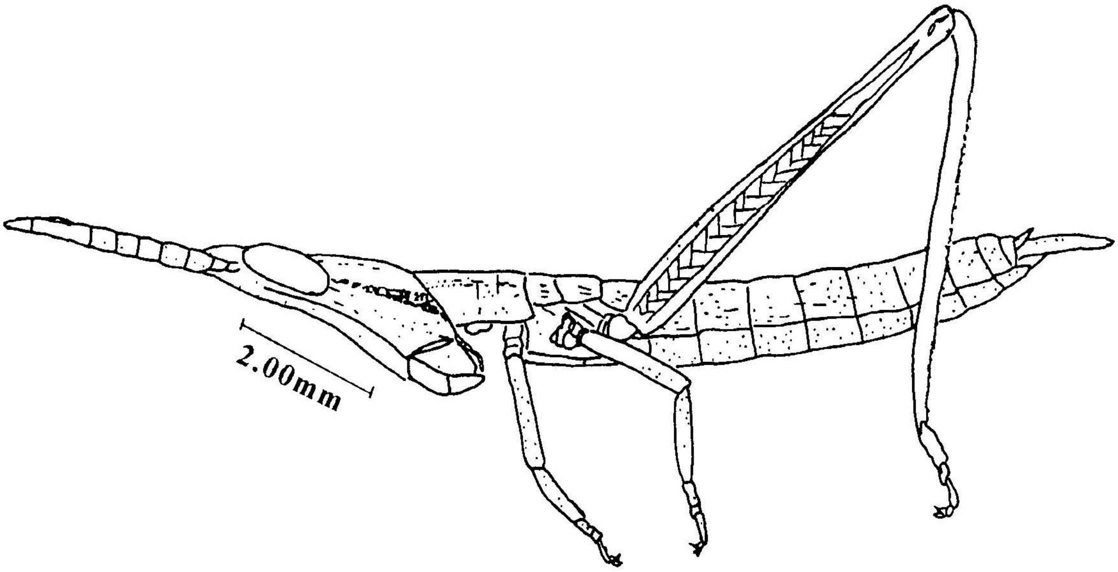


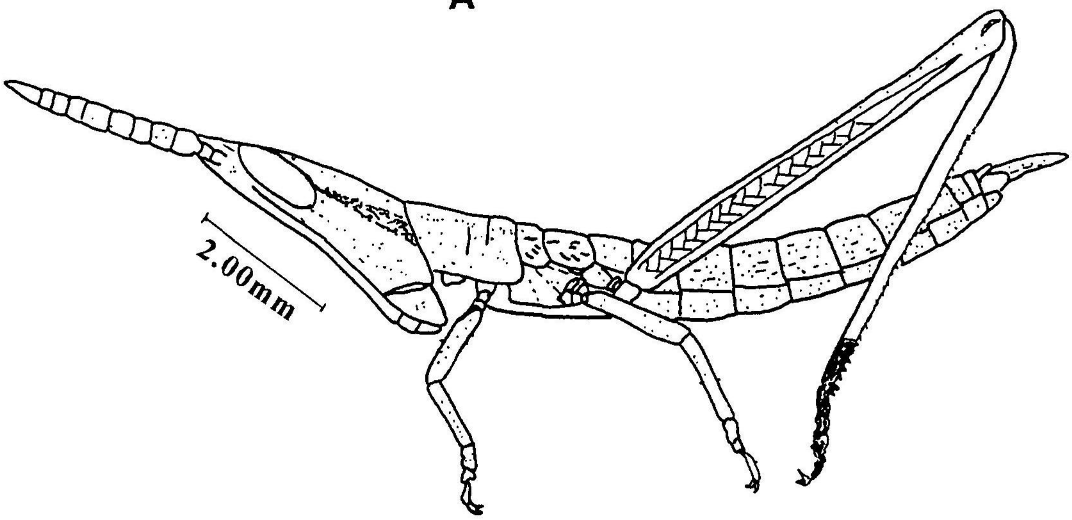
FIG.24. *Acrida exaltata* Walk.

A – I INSTAR (FEMALE)

B – I INSTAR (MALE)



A



B

FIG.25. *Acrida exaltata* Walk.

A – II INSTAR (FEMALE)

B – II INSTAR (MALE)

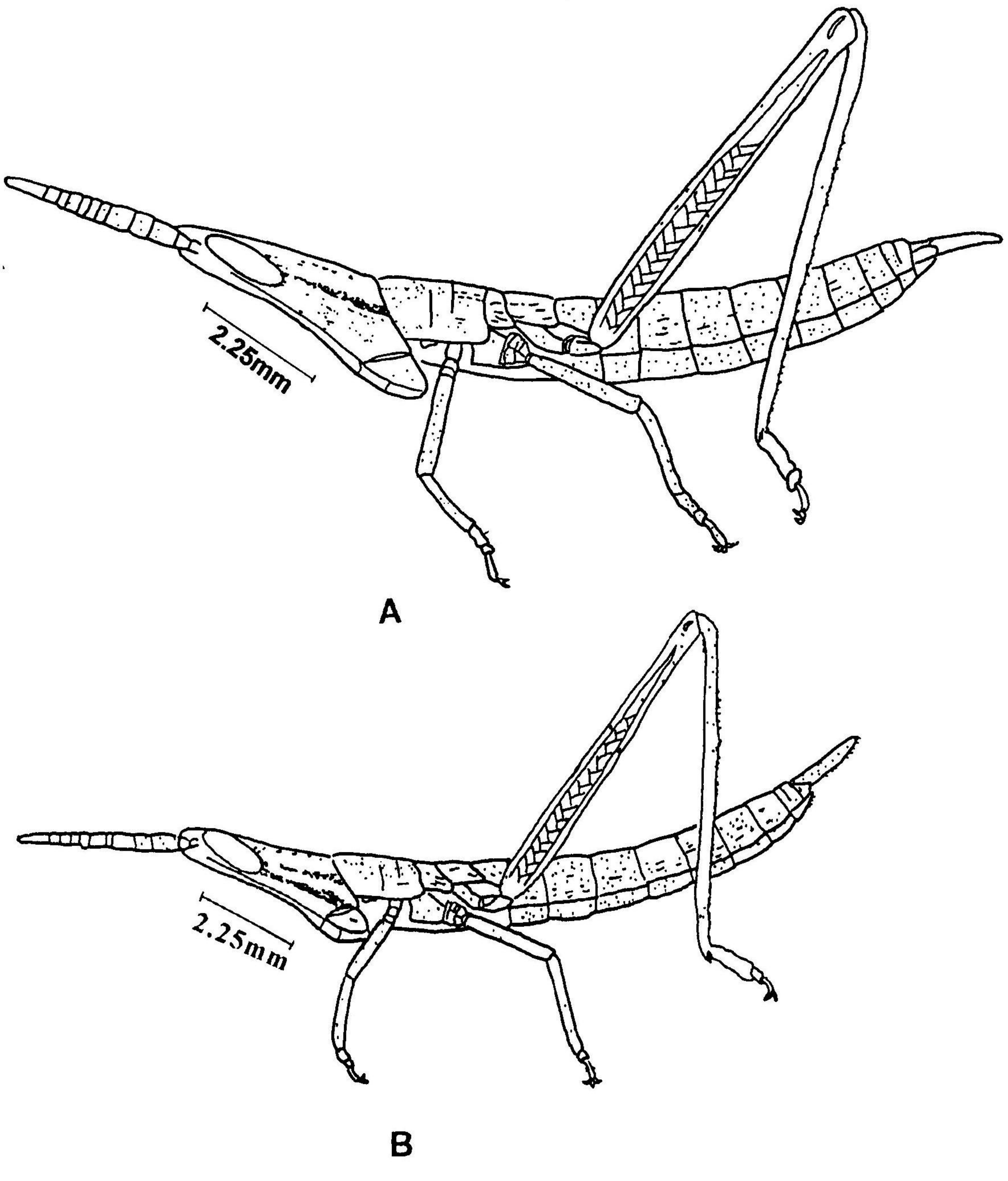


FIG.26. *Acrida exaltata* Walk.

A – III INSTAR (FEMALE)

B – III INSTAR (MALE)

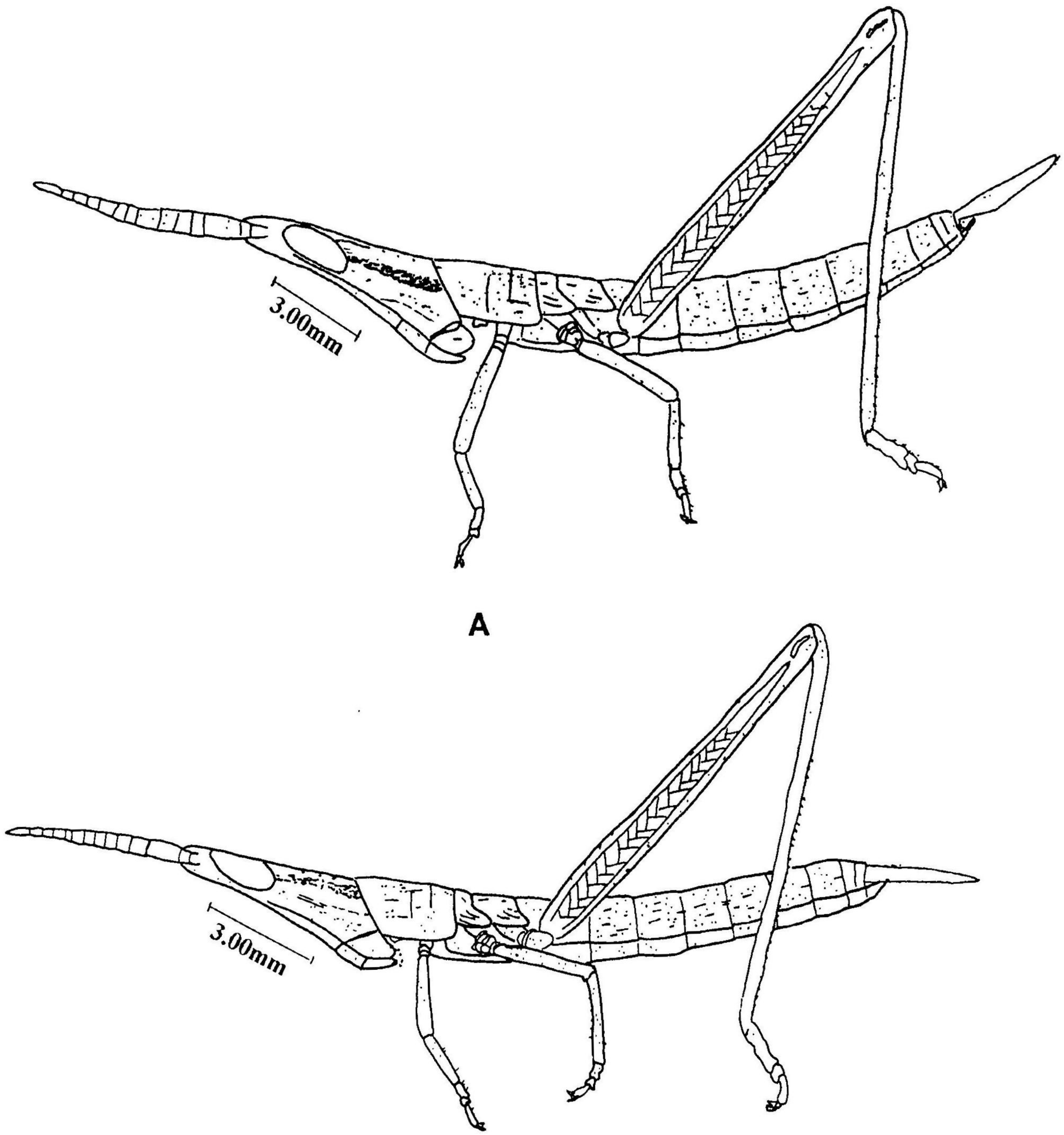


FIG.27. *Acrida exaltata* Walk.

A – IV INSTAR (FEMALE)

B – IV INSTAR (MALE)

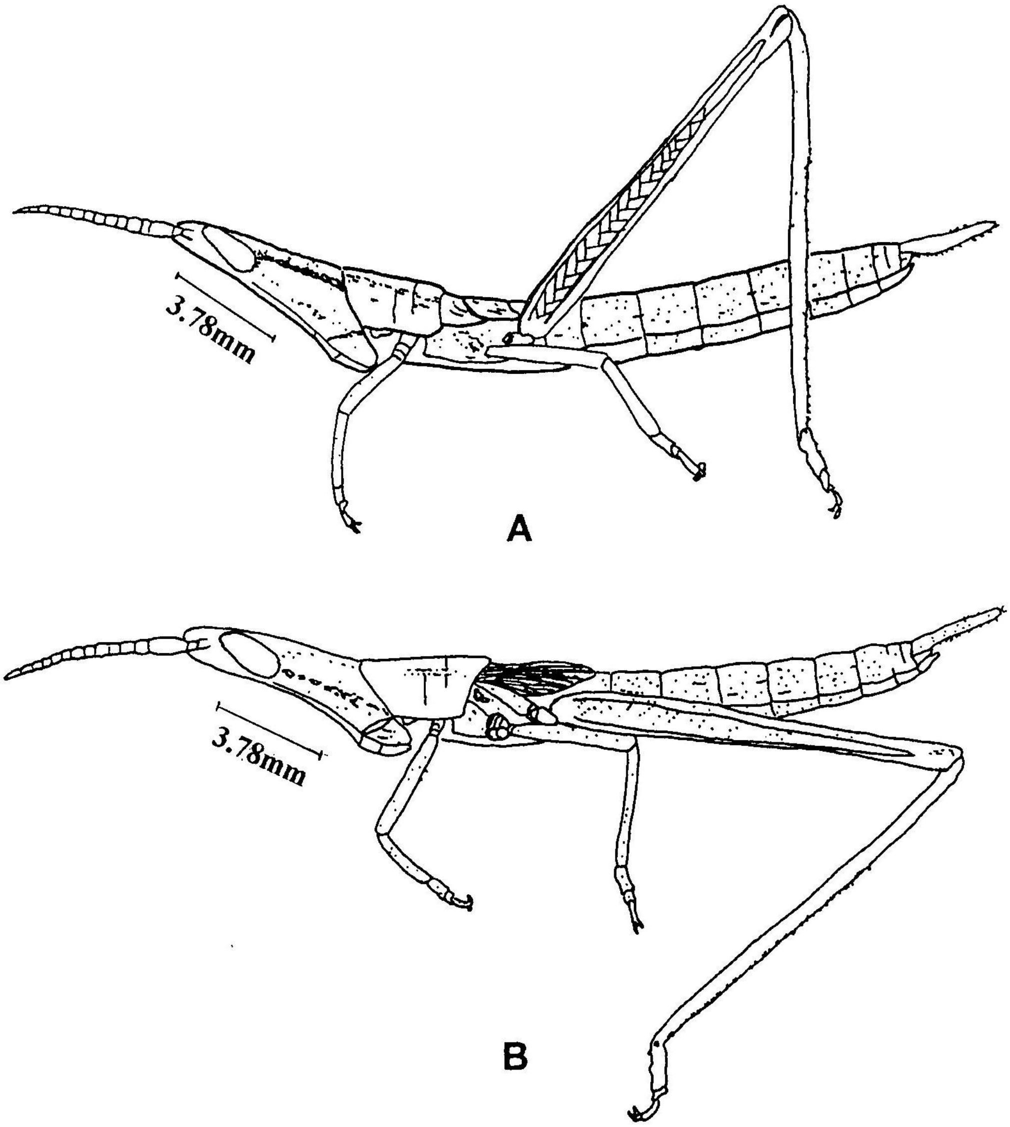


FIG.28. *Acrida exaltata* Walk.

A – V INSTAR (FEMALE)

B – V INSTAR (MALE)

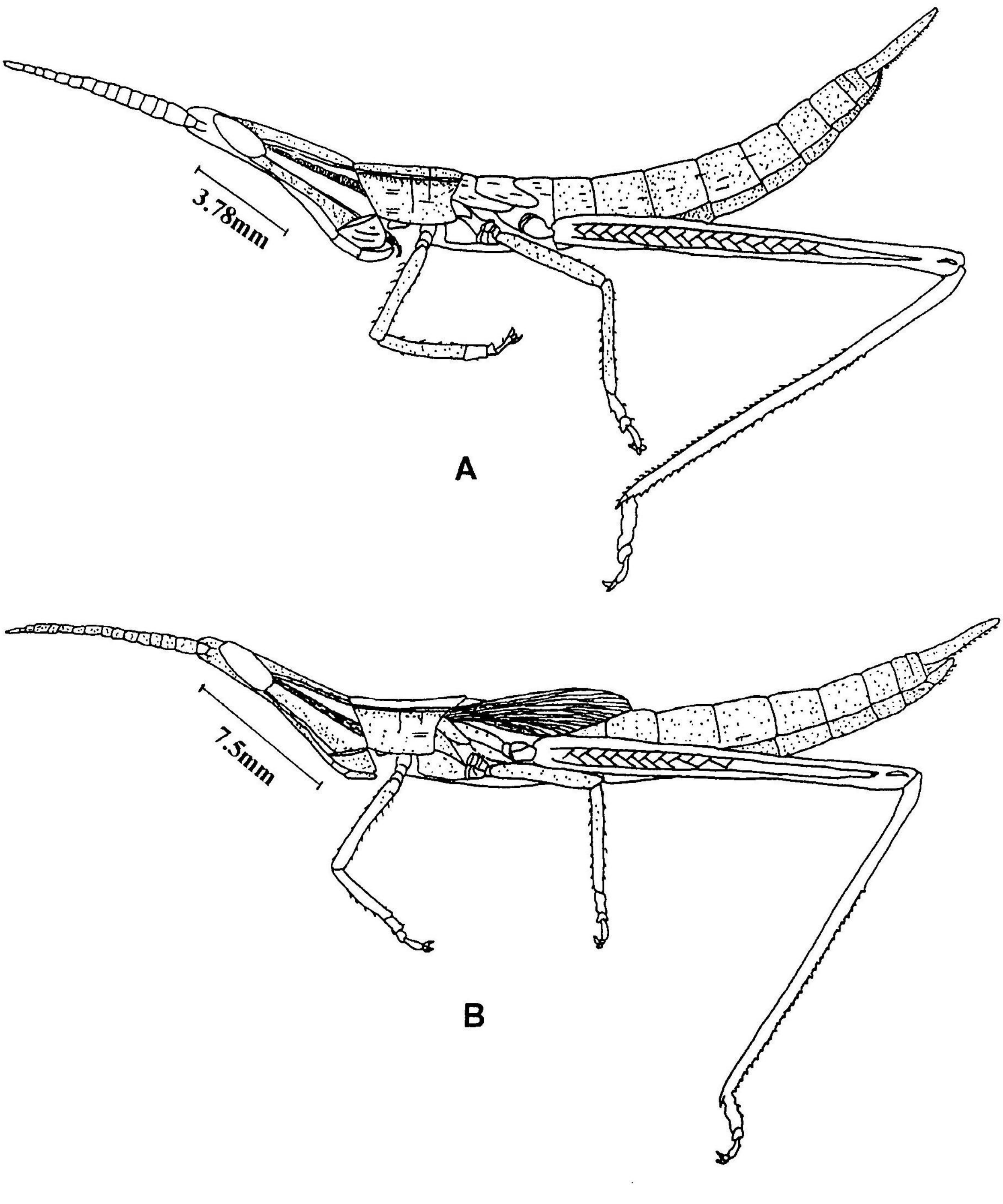


FIG.29. *Acrida exaltata* Walk.

A – VI INSTAR (FEMALE)

B – VI INSTAR (MALE)

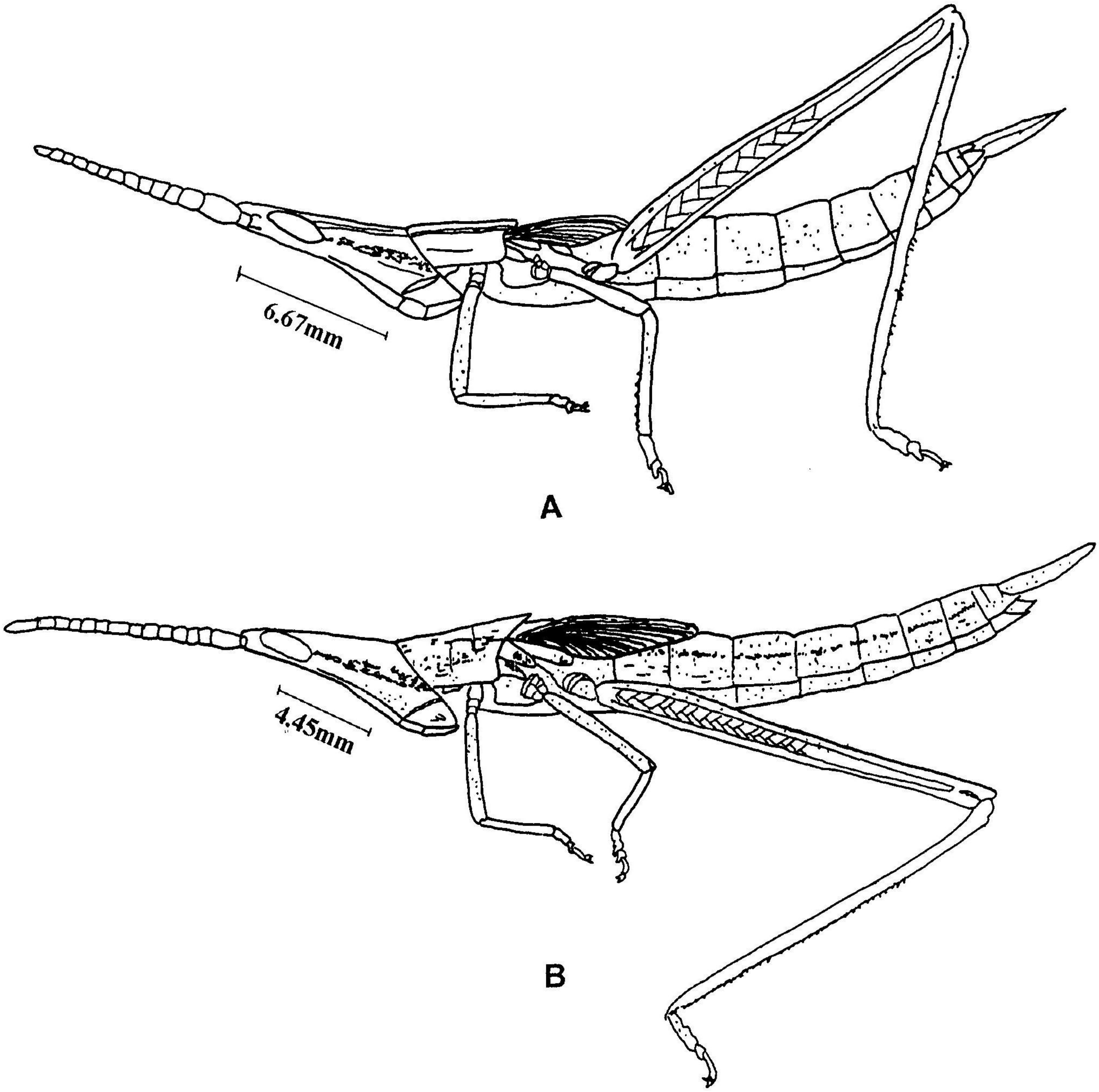


FIG.30. *Acrida exaltata* Walk.

A – VII INSTAR (FEMALE)

B – VIII INSTAR (FEMALE)

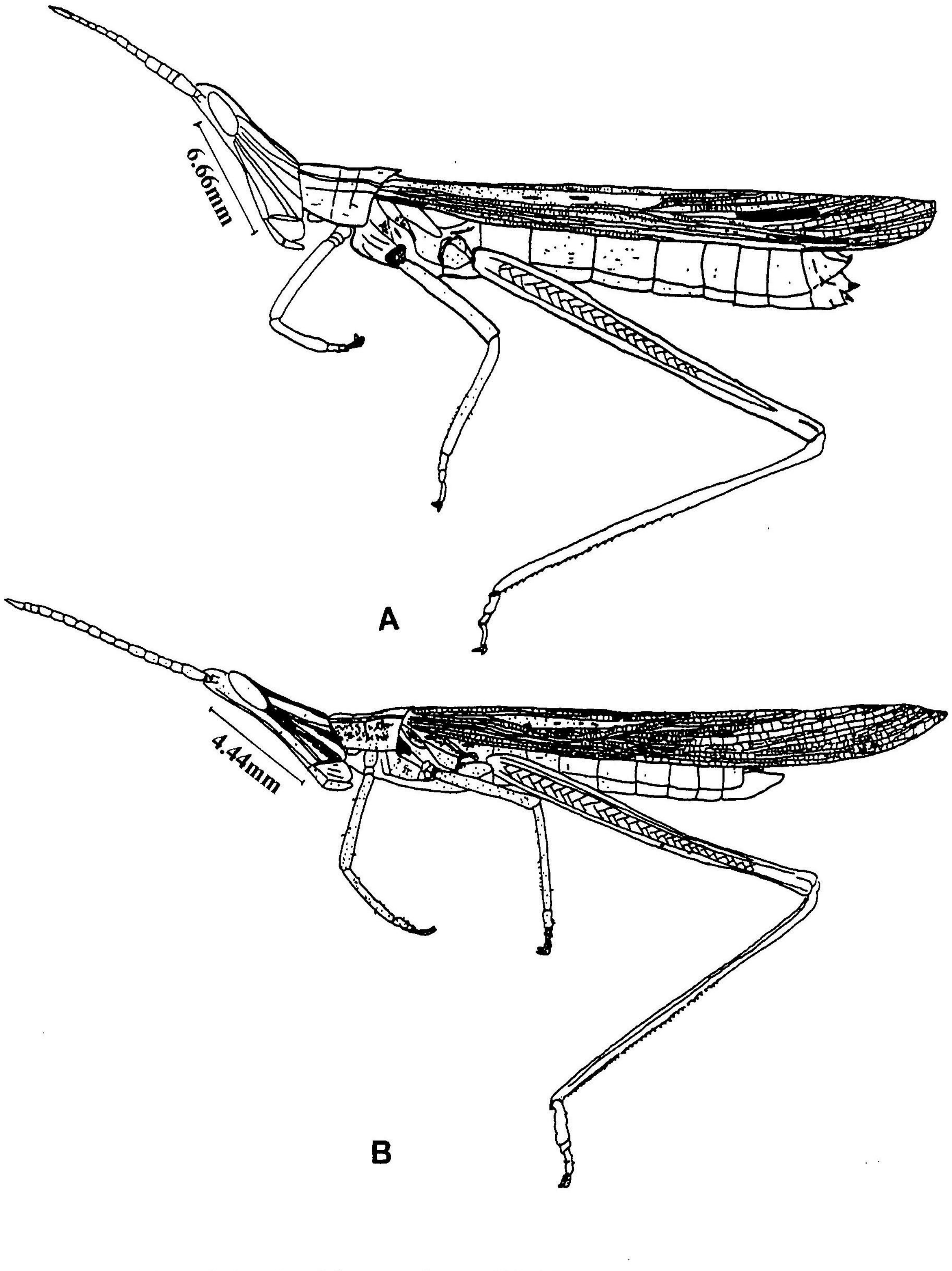


FIG.31. *Acrida exaltata* Walk.

A – ADULT (FEMALE)

B – ADULT (MALE)

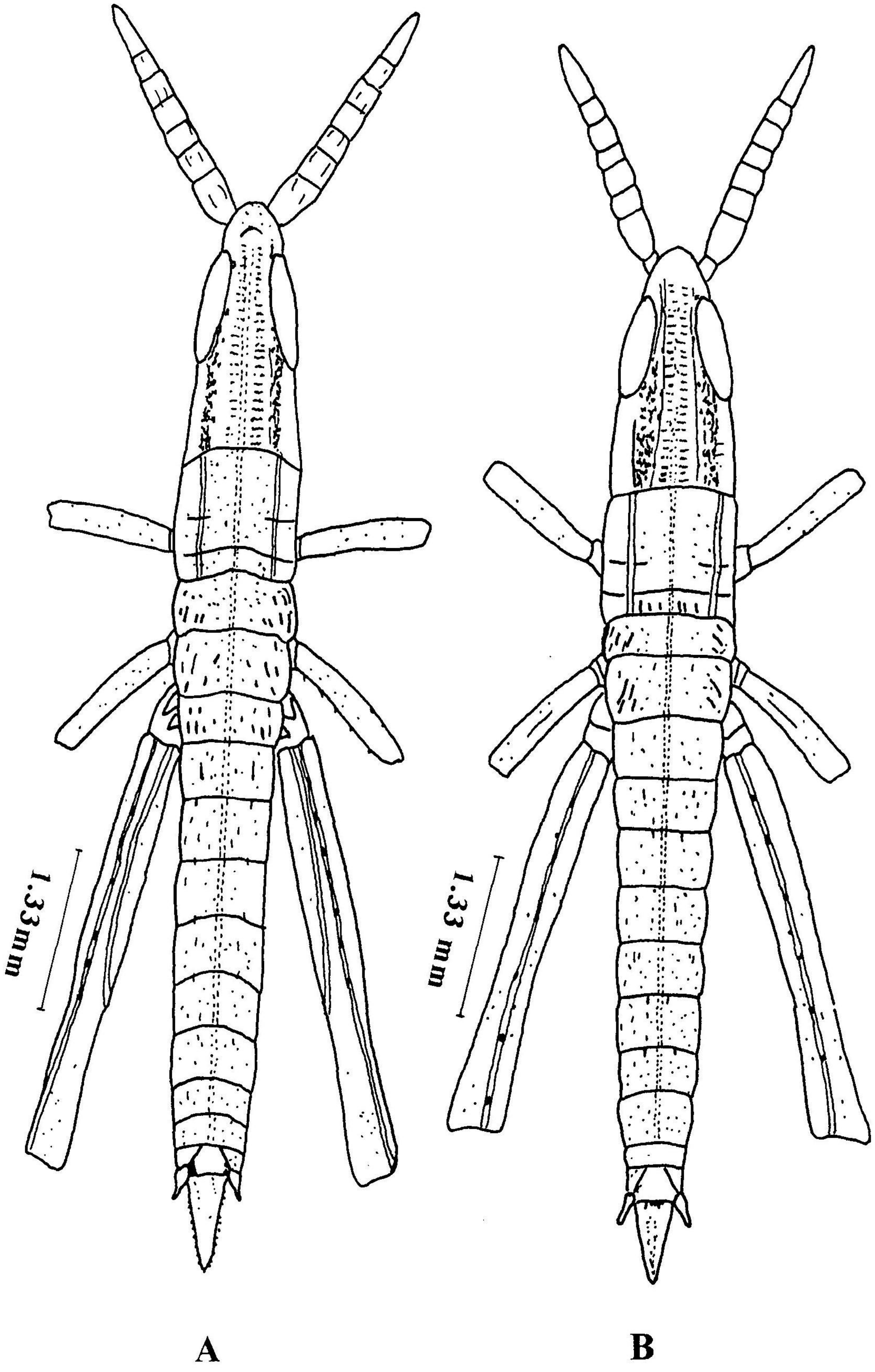


FIG.32. *Acrida exaltata* Walk.

A – I INSTAR (FEMALE)

B – I INSTAR (MALE)

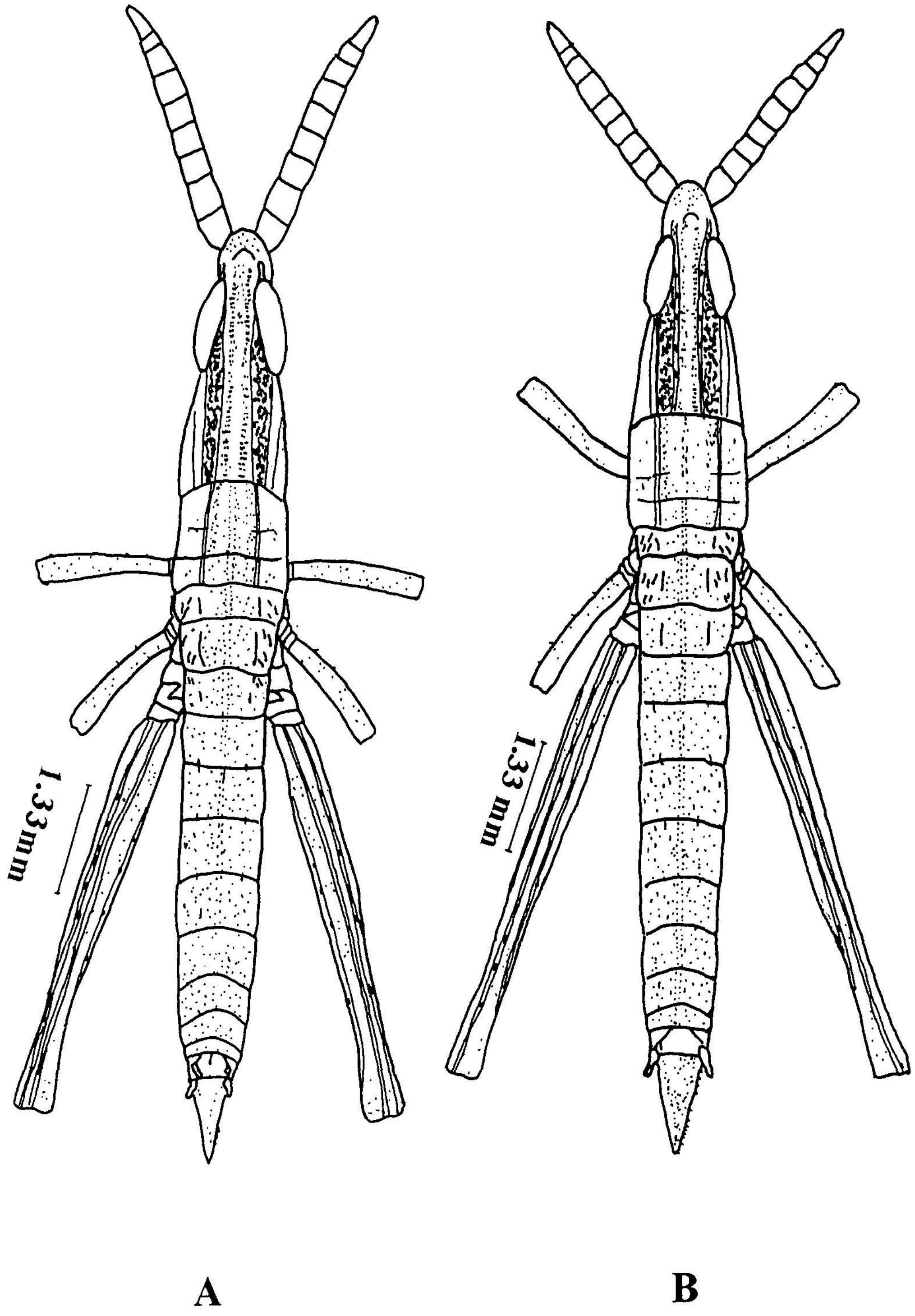


FIG.33. *Acrida exaltata* Walk.

A – II INSTAR (FEMALE)

B – II INSTAR (MALE)

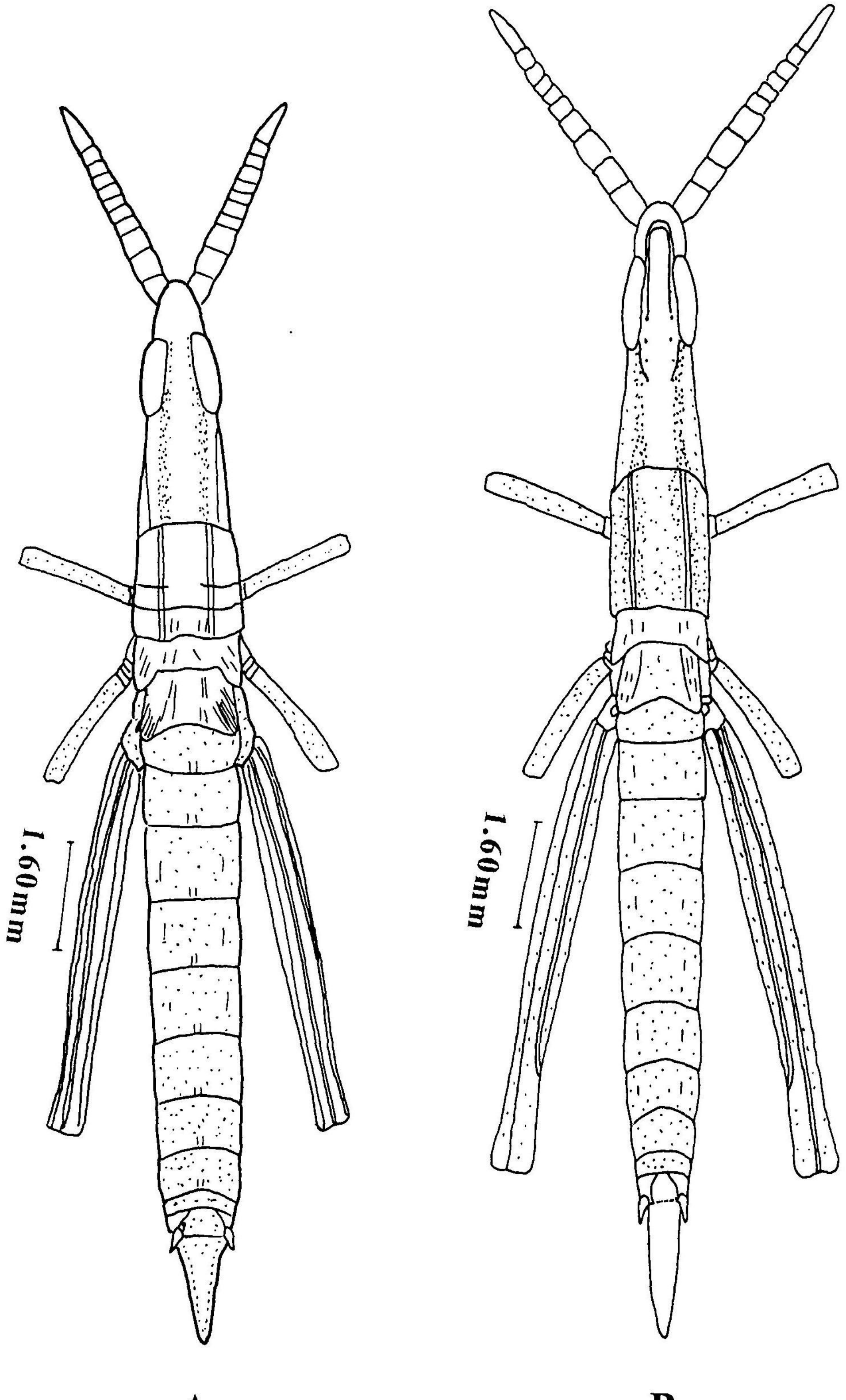
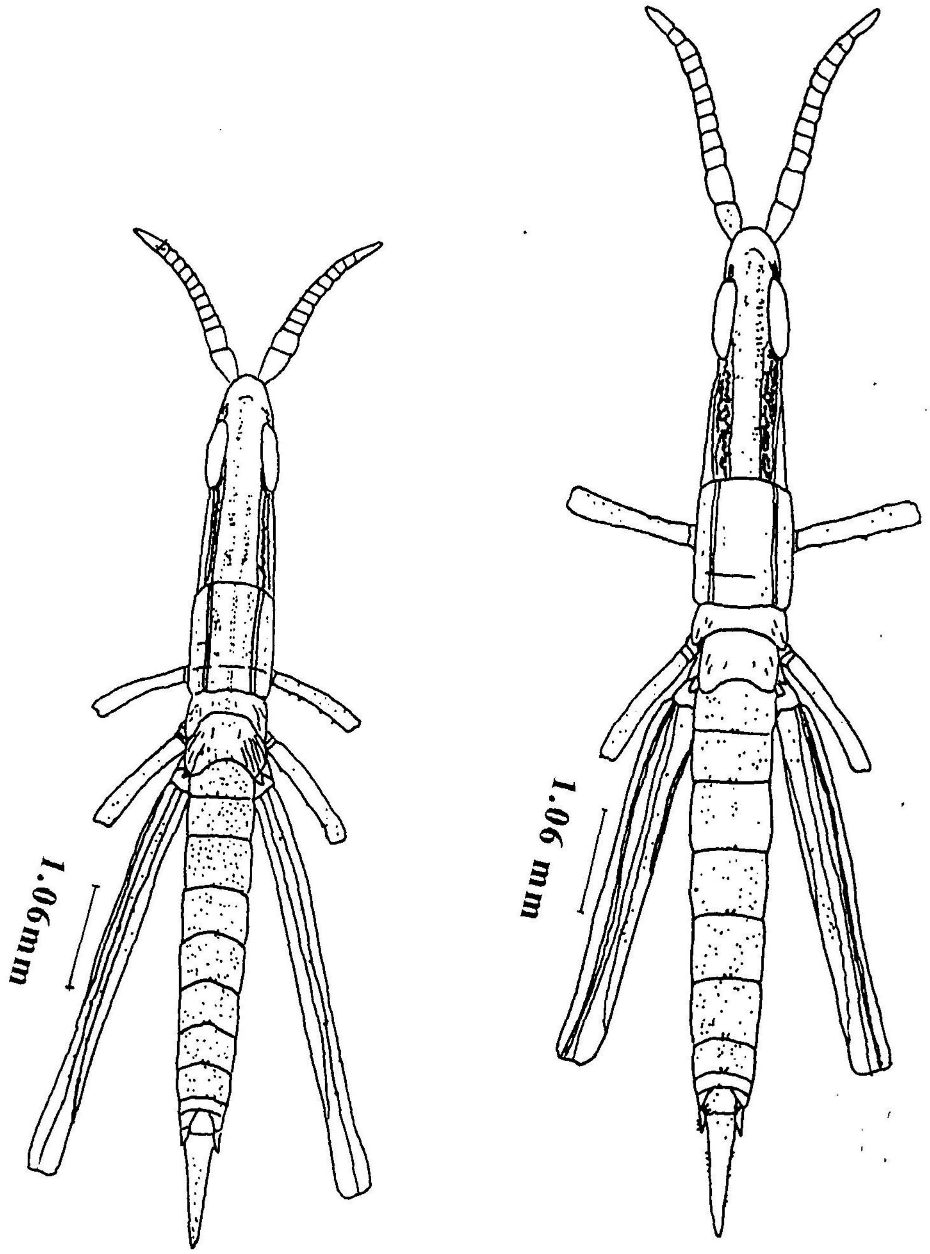


FIG.34. *Acrida exaltata* Walk.

A – III INSTAR (FEMALE)

B – III INSTAR (MALE)

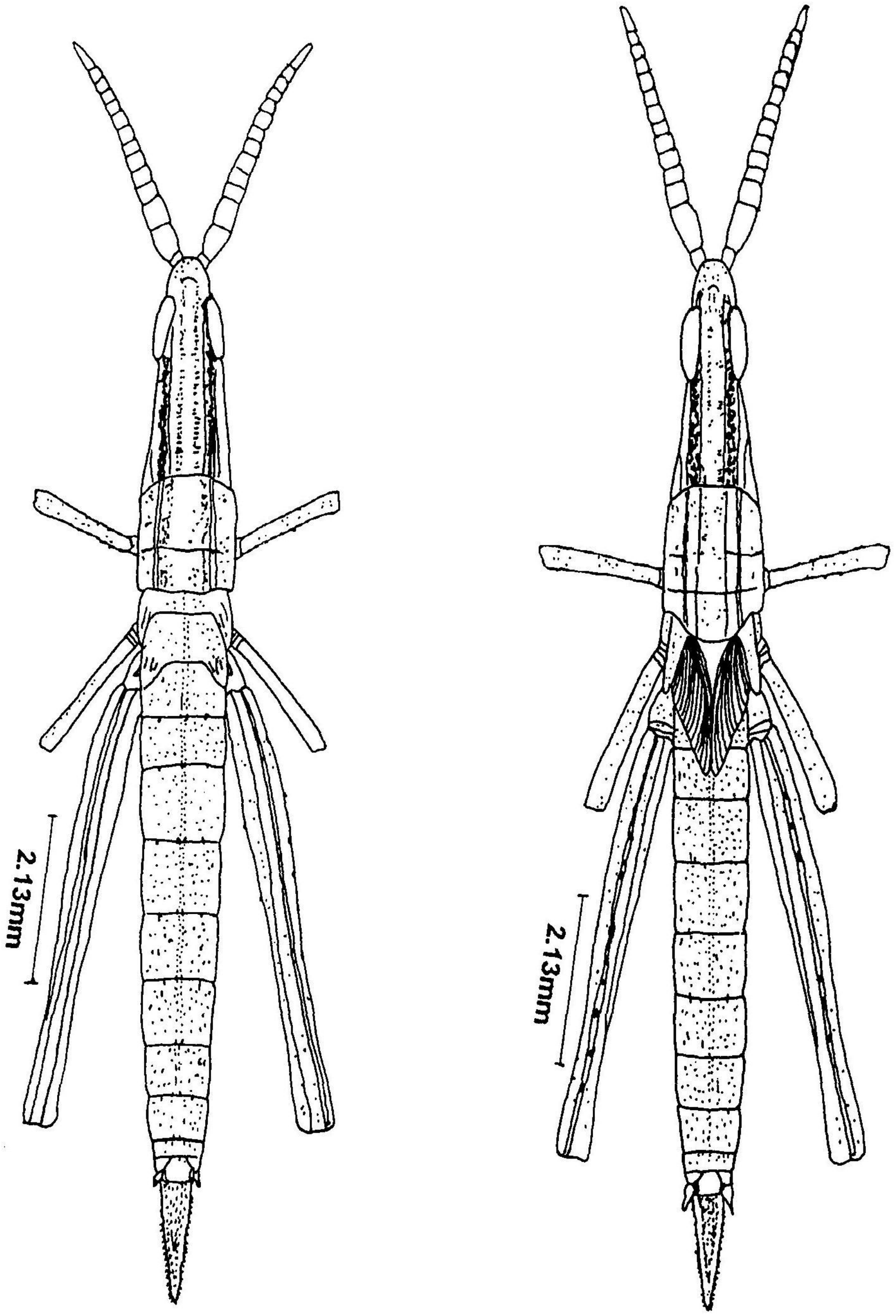


A B

FIG.35. *Acrida exaltata* Walk.

A – IV INSTAR (FEMALE)

B – IV INSTAR (MALE)



A B

FIG.36. *Acrida exaltata* Walk.

A – V INSTAR (FEMALE)

B – V INSTAR (MALE)

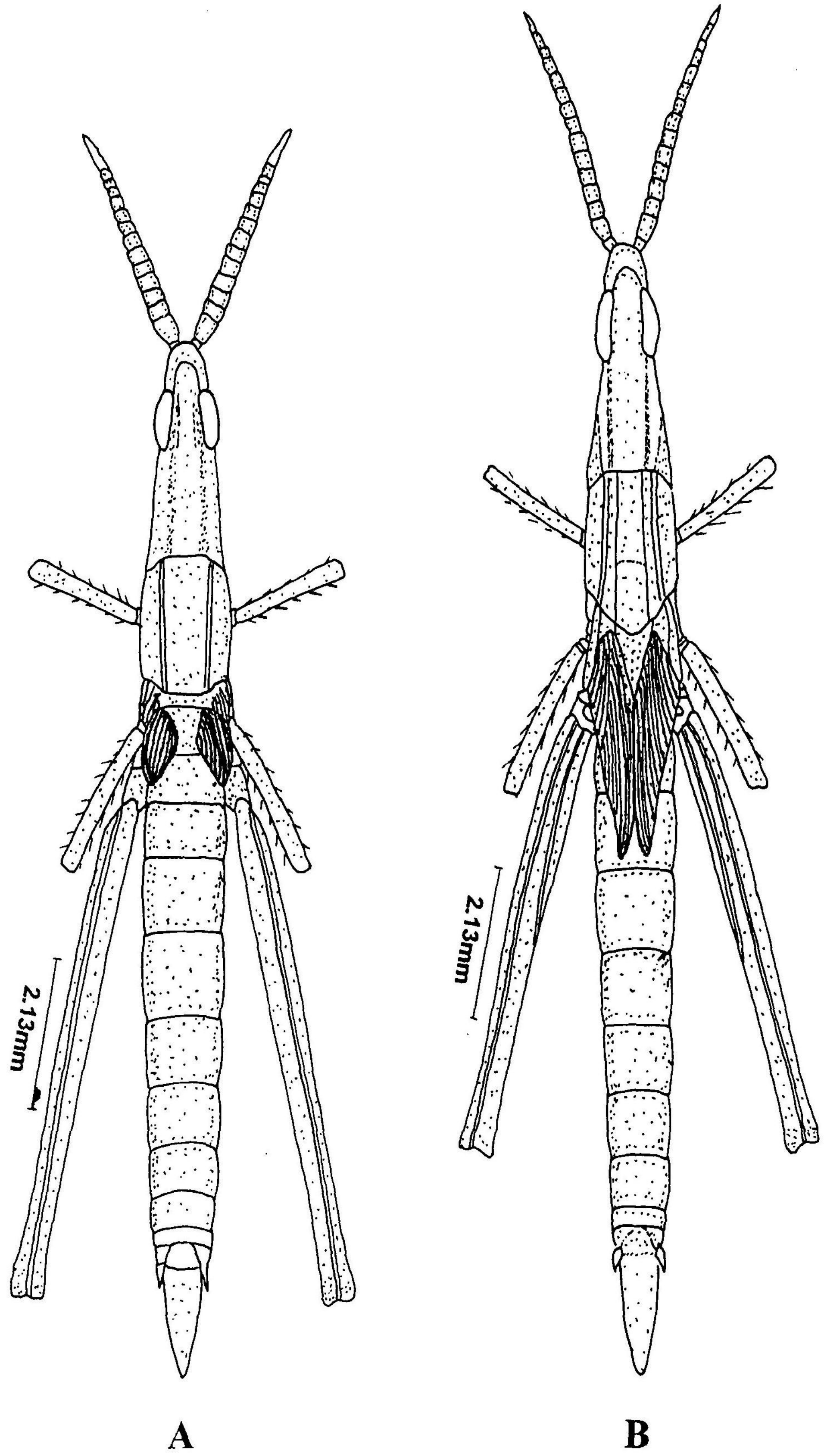


FIG.37. *Acrida exaltata* Walk.

A – VI INSTAR (FEMALE)

B – VI INSTAR (MALE)

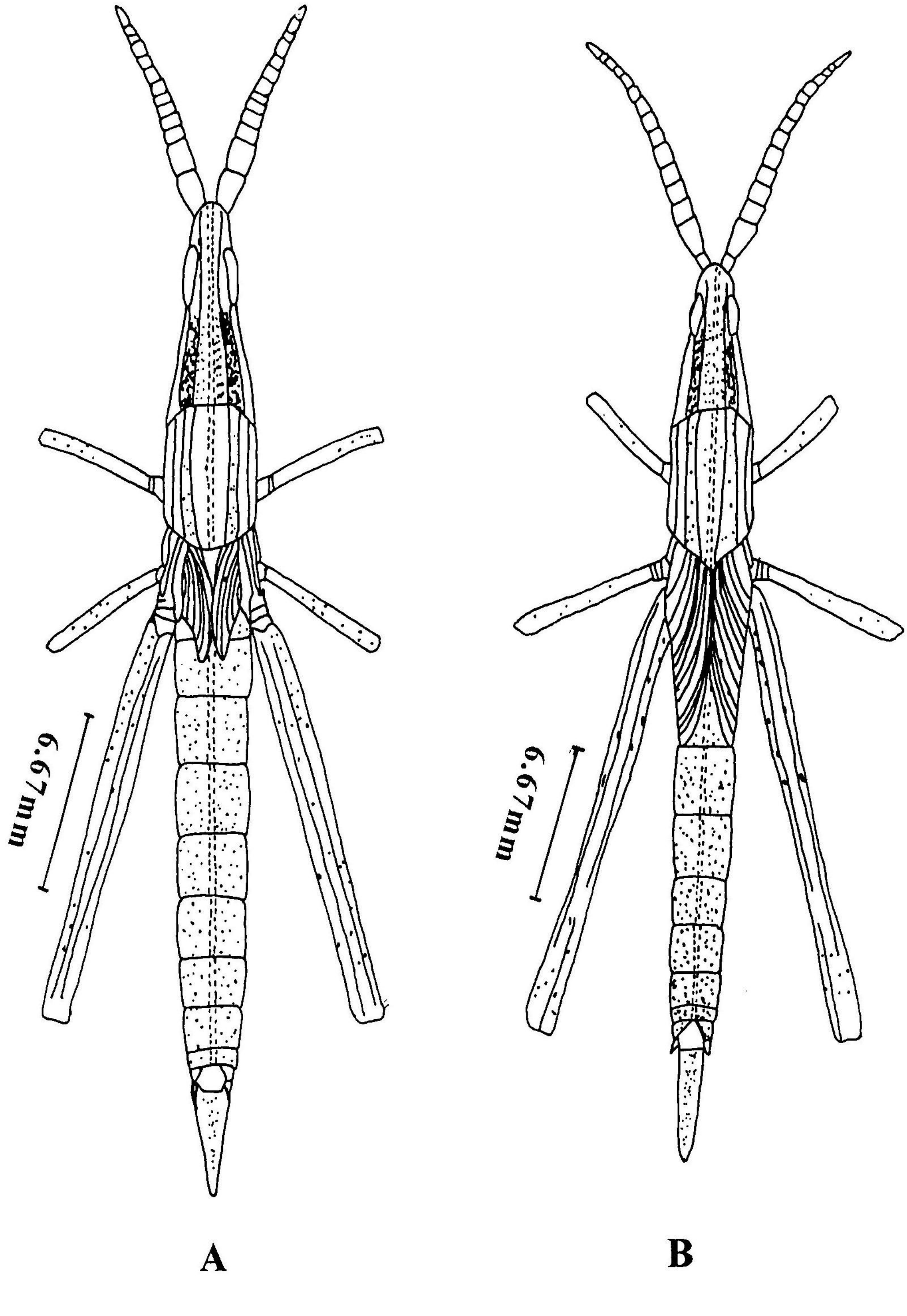


FIG.38. *Acrida exaltata* Walk.

A – VII INSTAR (FEMALE)

B – VIII INSTAR (FEMALE)

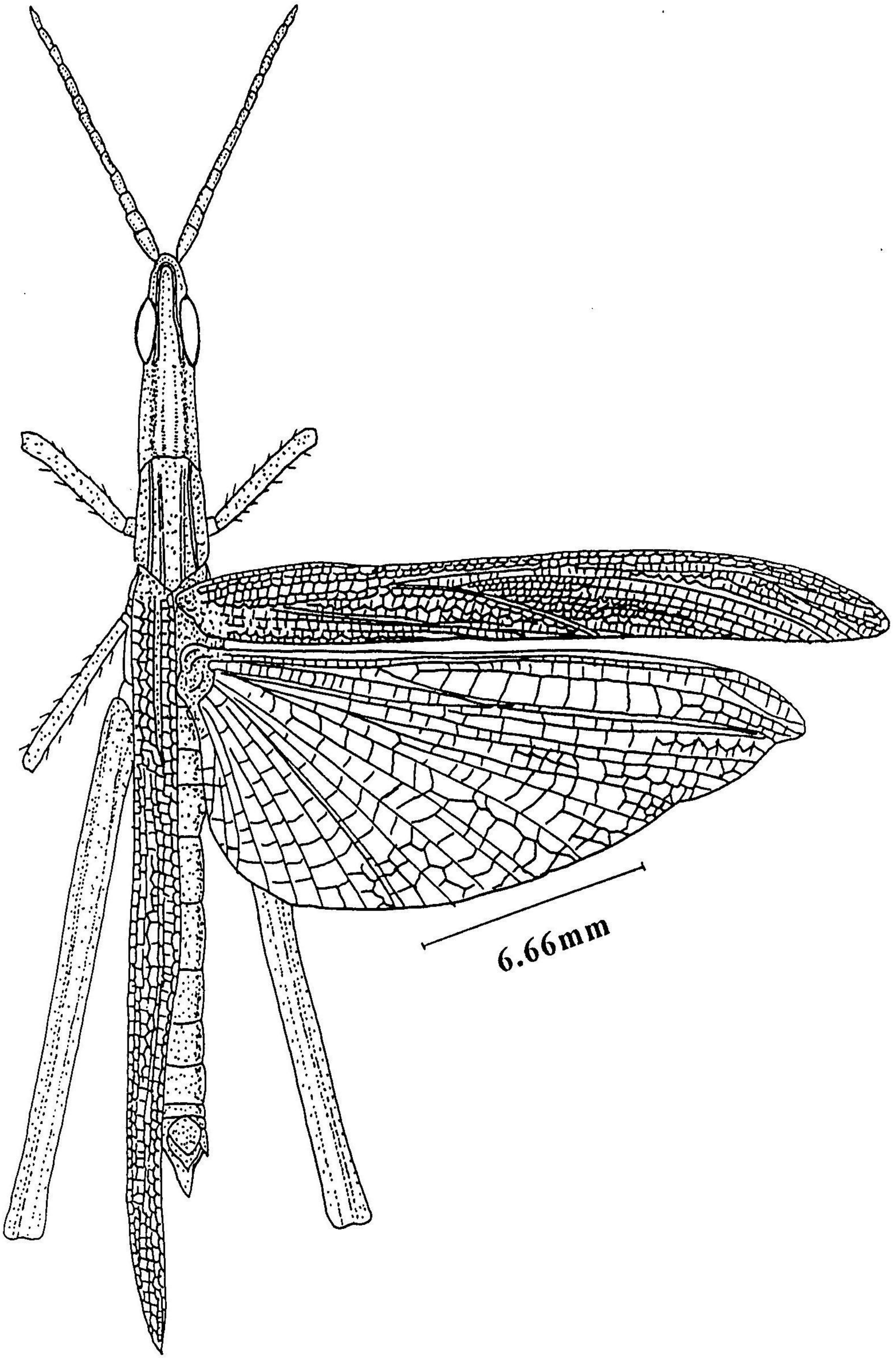


FIG.39. *Acrida exaltata* Walk. (MALE)

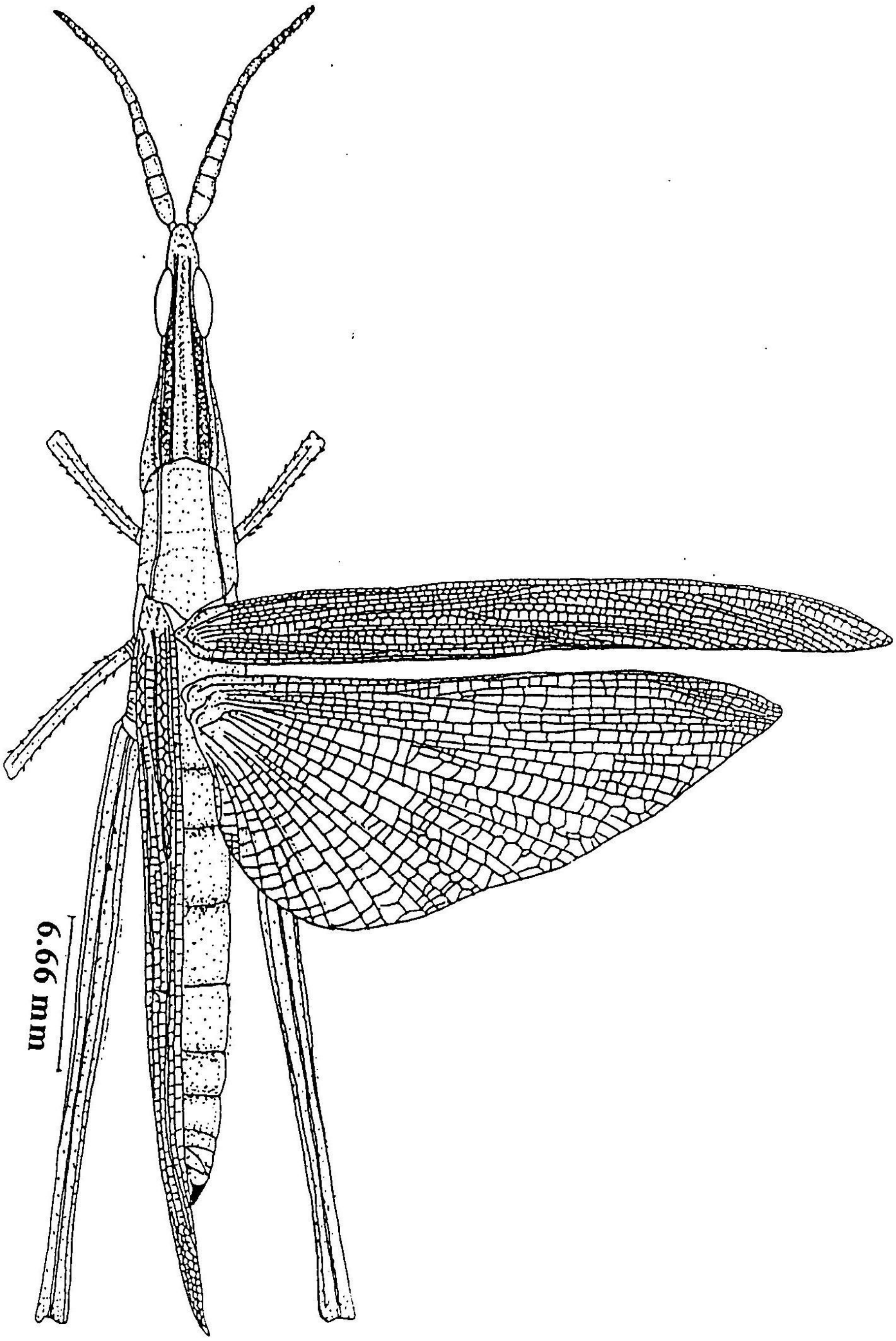


FIG.40. *Acrida exaltata* Walk. (FEMALE)

About thirteen body parts of all stages of hoppers including adults of both sexes were measured in order to have comparative rate increase and the developmental mean rate which have been tabulated and calculated and are self explanatory (Tables 6, 7). In the development of hoppers to prepare a key for the hoppers and the adults, the number of antennal segments have been considered quite significant.

The mandibles of the hoppers are typically of herbivorous type as these are overlapping and interlocking, incisor dents pointed; left dents not longer than right; molar lobe with several sub–conical dents (Figs. 23).

Application of Dyar's law:

The Dyar's law (1890) was applied in lepidopterous larvae. This law can also be applied in case of acridoids where successive formation of instars is a progressive development. The measurements of head width of the successive instars were made separately in both sexes and within the same sex.

The head width in successive instars increases in a geometrical progression (Fig. 41). The average increase in each

Table: 11. Application of Dyar's Law on the hoppers of *Acrida exaltata* Walk.

(10 replicates)

Sex	Hopper instar	Observed width of head of hoppers (mm)	Calculated width of head of hoppers (mm)
Males with 5 instars	I instar	1.14	–
	II instar	1.22	1.14 × 1.169 = 1.332
	III instar	1.45	1.22 × 1.169 = 1.426
	IV instar	1.82	1.45 × 1.169 = 1.695
	V instar	2.12	1.82 × 1.169 = 2.127
Males with 6 instars	I instar	1.14	–
	II instar	1.22	1.14 × 1.136 = 1.295
	III instar	1.45	1.22 × 1.136 = 1.385
	IV instar	1.75	1.45 × 1.136 = 1.647
	V instar	2.07	1.75 × 1.136 = 1.988
	VI instar	2.15	2.07 × 1.136 = 2.351
Females with 6 instars	I instar	1.14	–
	II instar	1.24	1.14 × 1.222 = 1.393
	III instar	1.64	1.24 × 1.222 = 1.515
	IV instar	1.92	1.64 × 1.222 = 2.000
	V instar	2.52	1.92 × 1.222 = 2.346
	VI instar	3.08	2.52 × 1.222 = 3.079
Females with 7 instars	I instar	1.14	–
	II instar	1.24	1.14 × 1.188 = 1.354
	III instar	1.64	1.24 × 1.188 = 1.473
	IV instar	1.92	1.64 × 1.188 = 1.948
	V instar	2.04	1.92 × 1.188 = 2.280
	VI instar	2.71	2.04 × 1.188 = 2.423
	VII instar	3.08	2.71 × 1.188 = 3.219
Females with 8 instars	I instar	1.14	–
	II instar	1.24	1.14 × 1.188 = 1.354
	III instar	1.64	1.24 × 1.188 = 1.473
	IV instar	1.92	1.64 × 1.188 = 1.948
	V instar	2.04	1.92 × 1.188 = 2.280
	VI instar	2.72	2.04 × 1.188 = 2.423
	VII instar	3.10	2.72 × 1.188 = 3.231
	VIII instar	3.74	3.10 × 1.188 = 3.682

Calculated width of head = Observed width of head × average ratio of increase in width of head

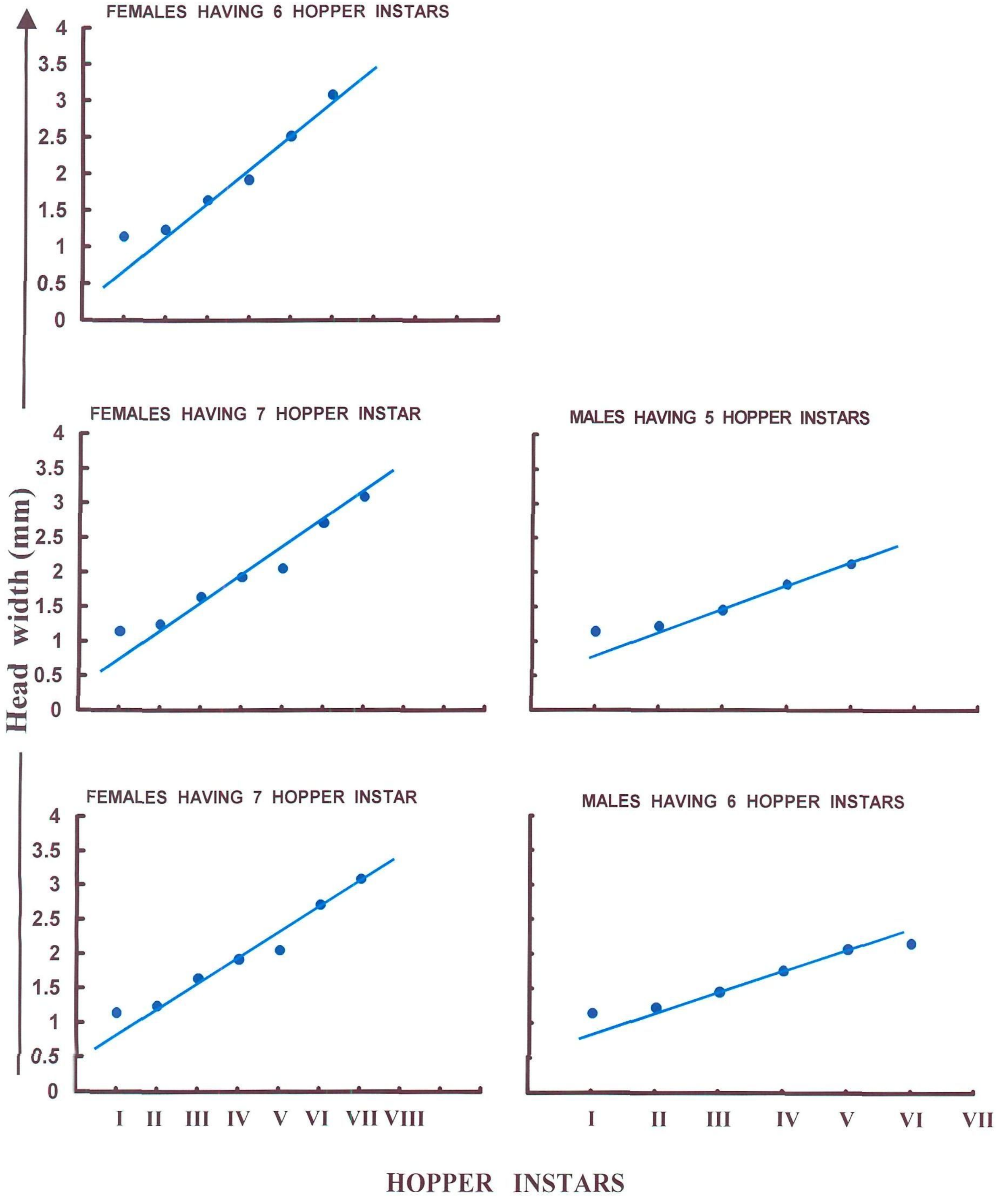


Fig. 41. Application of Dyar's law to *Acrida exaltata* Walk.

instar 1.169 and 1.136, respectively for the male hopper instars having 5– and 6–hopper instars to become an adult stage and 1.222, 1.188 and 1.188, respectively for the female hopper instars having 6–, 7– and 8–hopper instars to reach the adult stage. The calculated head width is found close to the observed head width (Table 11). These figures are enough to determine the instars and eliminate any possibility of missing an ecdysis in the life–cycle. Although the above figures are not completely identical in nature but these are sufficiently close to infer that the increase in head width follows Dyar's law. The slightest variation in ratios may be due to less number of measurements in each instar and also because of sex differentiation and variation in number of instars.

(ii) LIFE CYLCE IN THE FIELD:

There are two generations in a year, the first hatching was recorded in June, 2001 and such hatchings continued up to August. Development continues up to October and it is in this month that they attain maturity and complete copulation takes place. By November egg–laying takes place which goes up to second or third week of November. Such eggs hibernate during the month of December and January, which is often regarded as typical of acridoids and common in temperate climates with cold winters as found in Aligarh. This may be considered as a winter diapause. Hatching starts in the first or second week of February and continues up to the last week of March. The second completes hopper development up to April or first week of May and then they attain sexual maturity. In this manner second generation starts from the month of February and is completed in April. Thus the first generation passes through the fourth week of April to the first week of November and the second generation passes through the second week of November to the third week of April. There was no obligatory diapause but facultative or winter diapause cannot be ruled out. The above description is based on complete recordings of two generations during the year 2001–2004. Overlapping generations and the population of *Acrida exaltata* throughout the year suggests that there are more than two generations a year. It can be added on the basis of field experiences that this species cannot be placed in diapause category.

There are considerable variations in the hatching dates of *Acrida exaltata*, which can be attributed to differences in temperature regimes experienced by egg–pods laid with different exposures, in the type and moisture contents of the soil and in other macro–meteorological factors. These were not investigated further as the present studies were carried out mostly under controlled and laboratory conditions.

The seasonal variations in the population of *Acrida exaltata* in different months of the year, 2001–2003 are based on fortnightly captured for counting purposes in accordance to the temperature, relative humidity and rainfall of different months (Figs. 5, 6,7 & 42, 43).

It was found that the adults available in the month of December and January can sustain cold regime of temperatures but the reproductive development remains suspended. Likewise, the hopper stages, mostly the late instar hoppers found in severe cold can also sustain low extremeness of temperature with slowest developmental rate. These findings suggests that extremes of low temperature do have a bearing on the hopper and adult temporary diapause, which is not a true diapause and can be attributed as to 'combat period' with ecological odds like two temperatures. Actually this is simply a suspension of developmental activities for the time being, showing ability of an ecological adaptation.

CHAPTER – IV

(B) POPULATION STUDIES

The population studies of *Acrida exaltata*, take into account seasonal variations in numerical abundance of all stages with special reference to variations in sex populations. In addition to it, special importance was attached to its small scale movements.

(a)Seasonal variations:

Acrida exaltata is found, throughout North India, year round even during extreme cold and hot weather. It is mostly abundant in short grasses like *Cynodon dactylon* Pers., and in tall grasses like *Panicum psilopodium* Trin. The local open savanna in Aligarh consists of the following grasses:

Cyperus rotundus Lin., *Paspalum distichum* Linn., *Seteria glauca* (L.) *Beauv.*, *Panicum psilopodium* Trin., and *Cynodon dactylon* Pers., was found to be mostly preferred by *Acrida exaltata*. It was also found that there were two complete generations in a year with overlapping of various nymphal stages of the third generation. In this way their numerical presence was recorded throughout the year. The most populous phase was found in September and

October, while the population at the lowest ebb in the month of December and January. The records of seasonal variation in the population of *Acrida exaltata* during 2001, 2002, and 2003 along with their population in different months of the year are shown in Fig. 42, 43. These data are based on fortnightly collection with all regularities. To co-ordinate and compare the relative abundance in different months of the year, meteorological data showing temperature, relative humidity (R.H.) and rainfall were also recorded. It is inferred that the increase in population is associated with the rainfall and sustained temperature, mostly on higher side, which has facilitated the hatching of hoppers, early development of hoppers and quick attainment of adult stage. For meteorological data see Figs. 5, 6, 7 and 42, 43 for seasonal variations.

It is noteworthy that the population of this species was never found as zero. It might have gone to a very low stage but there was no occasion when the *Acrida exaltata* was not found in and around Aligarh.

(b)Variations in sex population:

The ratios in the nymphal instars for the years, 2001, 2002 and 2003, were recorded in a number of samples, chiefly obtained

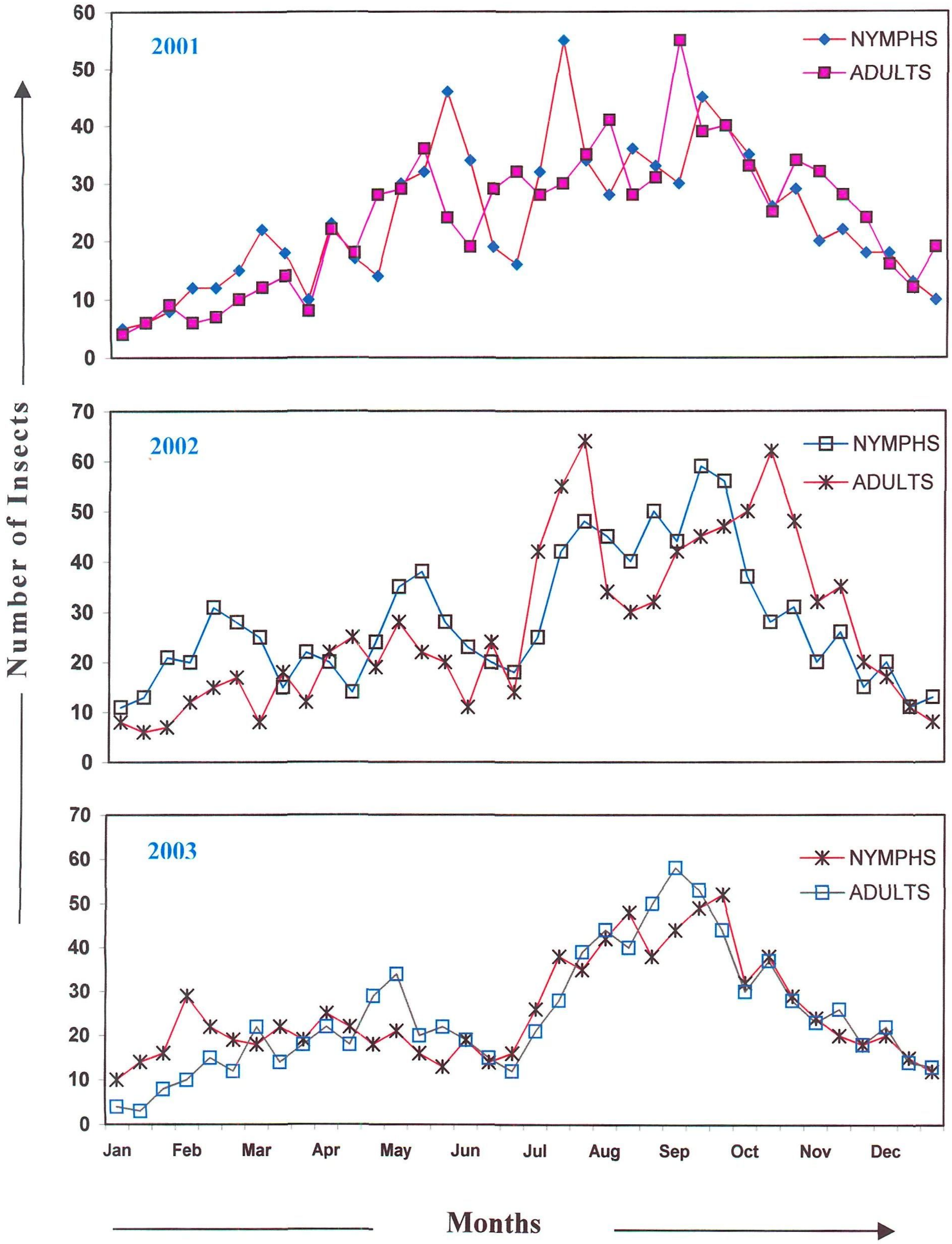


Fig.42. Natural population estimation of *Acrida exaltata* Walk.

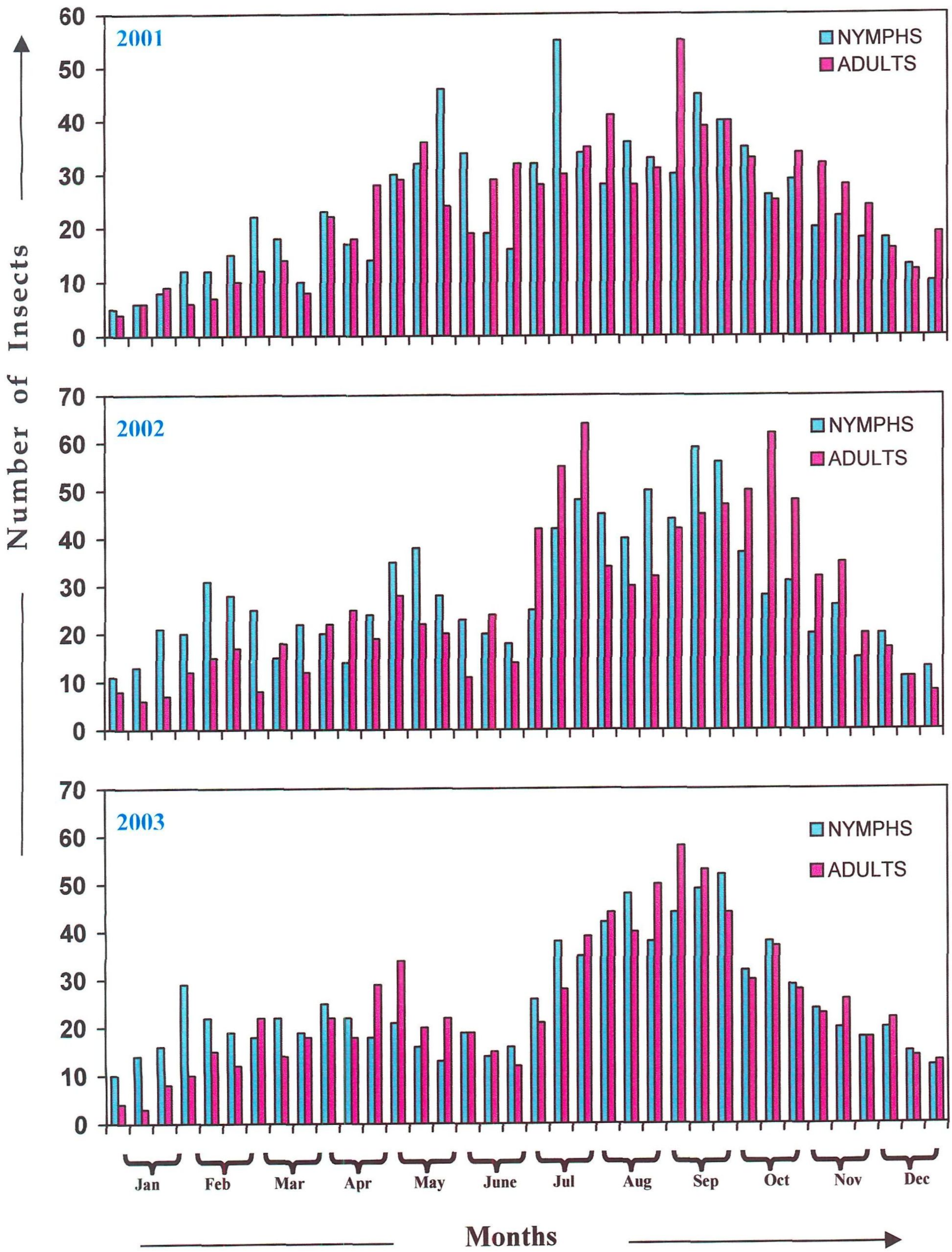


Fig.43. Natural population estimation of *Acrida exaltata* Walk.

by net sweeping. The sex ratios of the adult in the same year have been recorded for all the specimens. The sex ratio in *Acrida exaltata* was almost 1:1 in first instar hoppers; it oscillates in subsequent instars while in adults there was an excess of females. Sometimes, the excess of males was also recorded during good populations of third and fourth instar hoppers. This excess of male was mostly found in the month of September, which dwindles significantly in October but the females out – numbered males during October and November. This is probably because of short age of males and eventual death due to exhaustion after copulation with females. The female sex ratio starting from first instar down to the mature adult remains relatively incomparable with male sex instars and adults.

(c) Small scale movements:

During summer season of the years 2001 – 2003, an investigation, into the factors influencing movements in this grasshopper, was undertaken at Aligarh. To investigate the small scale movements of nymphal stages, alternative plots were marked. The available grass plot was divided into the following 3 alternative habitats as:

1. grass between 5 – 6 inches

2. grass cut to within an inch to the ground
3. bare ground with an occasional tuft of long grass

It was found that there is a significant difference between number of hoppers leaving and entering each alternative areas.

It was also observed that the slopes affect the number of grasshoppers entering short grasses only. This is to say; significantly more hoppers entered the short grasses at the bottom of the slope than at the top.

The small scale movements of the adults were recorded in the same manner and only two types of habitat, long and short grass were used (Fig. 44). Further, the effect of the time of the day was also considered during observations. It was observed that more males left the short grass than long grass, while more females left the long grass than short grass. Overall movements were more pronounced in males than in females. All observations are based on visual inspections during the course of experimentation with a view to assess the impact of habitat on various nymphal stages and adults as well. These observations may be of immense value to the plant protection for assessing the population fluctuations with reference to immature and mature stages.

Fig.44. Natural habitat of *Acrida exaltata* and *Phlaeoba infumata*

A – Open Savanna

B – Breeding Area

CHAPTER – IV

(C) ENVIRONMENTAL FACTORS

(i) TEMPERATURE:

Effect of temperature on various activities of the pest under study has shown a significant pattern regarding temperature gradient for hatching, incubation, daily rate of development and growth. Temperature is an abiotic factor of the environment and certainly plays a decisive role in the life of the insect. The effect of temperature as an environmental factor has been studied under four categories, namely, eggs, fertility, hopper development and locomotary behvaiour.

(a) Effect of temperature on eggs:

Table 4 includes the results pertaining to the effect of different temperatures on the hatching and hatchability of the eggs. The incubation periods have also been recorded. The relative humidity was constant (70±5%) but the temperature was variable from 10°C to 45°C. There is no hatching at 10 °C and 45 °C. This experiment was done with five hundred eggs at various occasions. As regards the incubation, the temperature ranging from 25°C and

35°C have shown degrees of incubation period. The percentage of hatching has also been calculated at various temperatures in Table 4. The temperature range of the survival percentage has also been recorded.

(b) Effect of temperature on fertility:

The fertility is referred to the number of eggs hatched in one life–cycle. Temperature gradient and its variables have shown various potentials of hatching or rather successful hatching and thus found to be 76.14% at 35°C when 985 eggs were incubated. Contrary to it there was only 60.83% hatching when eggs were incubated at 25°C. Such variabilities and their effects are shown in Table 4.

(c) Effect of temperature on hopper development:

Temperature does affect the developmental processes of various nymphal stages in this insect with special reference to two different sexes and their survival percentage at varying temperature. It was recorded that the temperatures, ranging from 25°C to 35°C, have various potentials of developmental rate and survival

Table: 12. Hopper duration, survival percentage, daily rate of development and growth index of *Acrida exaltata* Walk. at different temperatures

Indices	Sex	Temperature (°C)		
		25	30	35
No. of hoppers observed		100	75	50
Number of hoppers attained adult stage		40	48	42
Survival percentage (n)		40	64	84
Average hopper development period (P) (days ± S.E.)	Male	83.03±1.58	54.87±0.73	43.53±0.53
	Female	99.73±1.14	70.30±0.71	55.83±7.09
Development of hoppers/ day (%± S.E.)	Male	1.22±0.02	1.84±0.02	2.29±0.03
	Female	1.01±0.01	1.43±0.01	1.82±0.04
Growth index (n/P)	Male	0.205	0.461	0.675
	Female	0.230	0.550	0.977

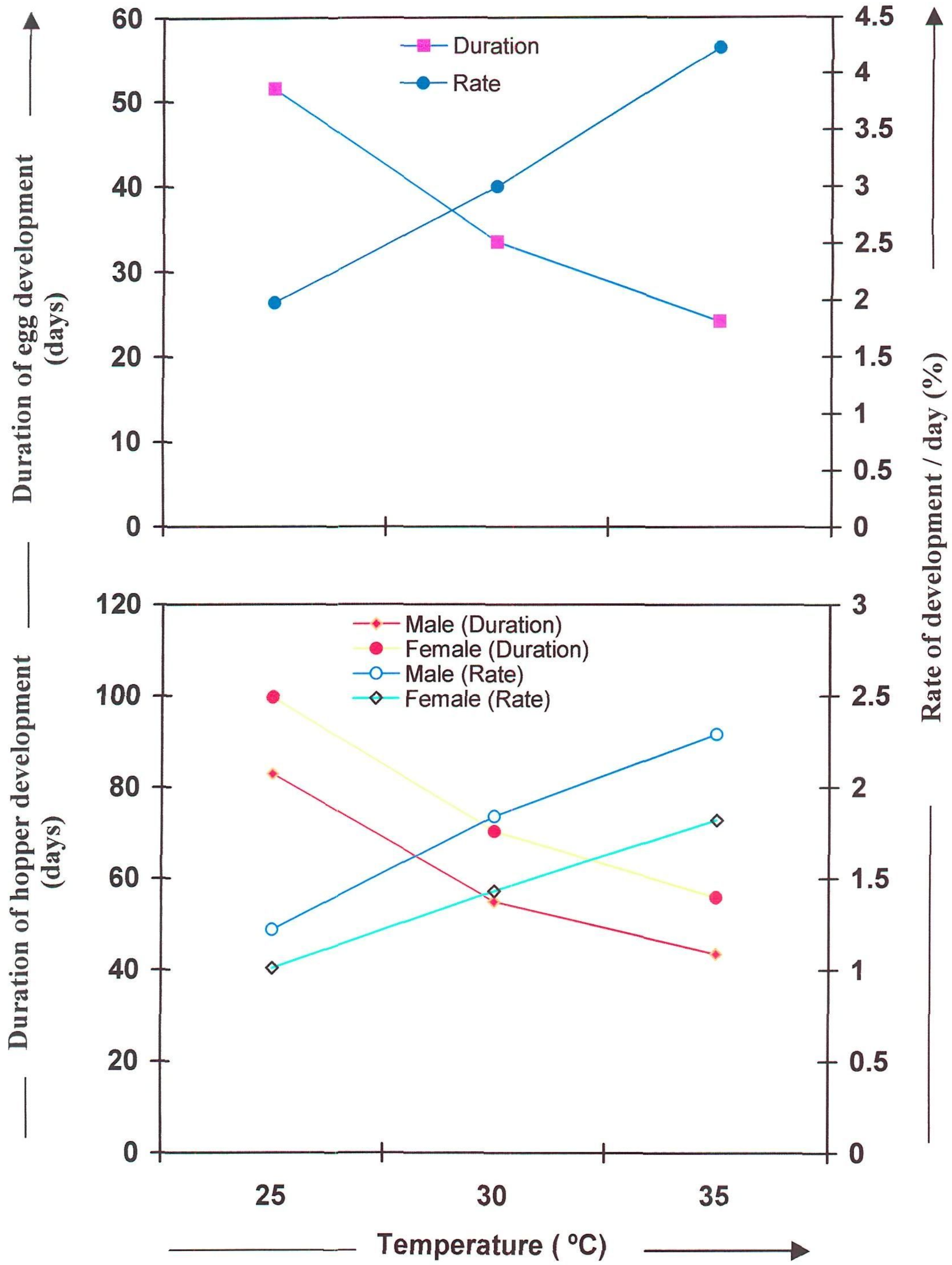


Fig.45. Graphs showing the effect of temperature upon duration (days) and rate of development per day (%) of eggs and hoppers of *Acrida exaltata* Walker.

percentage of hopper was found to be highest at 35°C as 84% (Table 12). The developmental rate of the hopper period along with per day developmental rate was found to be highest at 35°C. These observations seem to be in agreement with the natural life and living in wilderness with variables of abiotic factors.

(d) Effect of temperature on locomotory behaviour:

In an experimental cage all the nymphal instars were studied at different levels of temperature maintained constantly. The slowest locomotory activity was found at 10°C, which gradually increased when transferred to 25°C and became maximum between 30°C and 35°C. The brisk locomotory behaviour in all nymphal stages including newly hatched adult was raised to more than 44°C eventually causing death.

(C) ENVIRONMENTAL FACTORS

(ii) HUMIDITY:

The relative humidity of the air does affect various physico – ecological activities of acridoids as evident from the literature available. The kinetic effect of humidity has also been significantly studied. Humidity has its limits and creating zone of variable humidities and subsequently the activities of hoppers and adults have been recorded differently in wet and dry zones, respectively. The present observations are based on a constant temperature and variables of humidity in order to ascertain the effect of only relative humidity of soil, oviposition sites, on the development of hoppers and fecundity of the pest under study.

(a) Effect of soil moisture on egg development:

Effect of soil moisture on egg development was carried out in complete absence, presence and in abundance or excess of moisture in the soil.

In the present experiment, three egg–laying tubes with egg – pods were selected in which not even a drop of water was provided in first one while the second one kept barely moist and the third one remained flooded. The eggs in the first tube in which the moisture was completely absent failed to hatch, while in the second set where the soil was continuously moist, yielded about 78% hatching and in the third set, which was flooded, the eggs were completely destroyed.

(b) Effect of moisture on the selection of oviposition sites:

The present species under study was tested with three different soils namely, completely dried, moist and flooded.

Various mature females were forced to lay eggs in these tubes. Only the tubes containing moist soil were selected by the females for egg–laying and the other two tubes with dry and flooded soils were completely avoided.

(c) Effect of relative humidity on hopper development:

It is evident from available literature that development is affected with the absence and presence of relative humidity, therefore, the present set of experiment was undertaken to observe a similar effect of available humidities on the development of the species as found with the variable temperatures. Completely dry conditions with 5–10% R.H. decrease the development and affect the general health of the hoppers and prolong the life–span. Most preferred relative humidity ranges between 50–80% with relatively normal development of hoppers and have shown normal completion of life–cycle span. However, humidity alone around 100% is not conducive to normal developmental process but is rather detrimental.

(d) Effect of relative humidity on fertility:

During this investigation, it was found that the fertility was very low (10 – 12%) at relative humidity ranging from 5–15%, while it has been at a high level (70–80%) when subjected to humidity ranging from 50–80%. It was noted critically that the combination of preferred temperature and humidity may raise fertility to a level of 90% success.

(C) ENVIRONMENTAL FACTORS

(ii) FOOD:

(a)Effect of food plants on the development:

The quality and quantity of food has a direct bearing on the development of various stages of insect during the completion of life–cycle. In the present study various food plants have shown significant effects on the development of nymphal and adult stages. Table 13, shows the results of the effect of different food plants on the hopper development period and the daily rate of development of *Acrida exaltata*. It was found that the food plants do affect sexual and hopper development period and development of hoppers per day (Fig. 45). *Saccharum officinarum* and *Brassica oleracea* var. *botrytis*, though dominant food plants in insect's breeding areas, have different effect on the hopper developmental periods and on sexes which in case of latter shown the minimum developmental period to be 33.20 days in males & 38.40 days in females and in case of former to be 79.30 days in males and 88.50 days in females. The decreasing effectiveness of the other 9 food plants tested for the developmental period are of significance. Similarly the development of hopper per day in terms of percentage in relation to

Table: 13. Effect of different food plants on the hopper development period and daily rate of development of *Acrida exaltata* Walk. reared at 35 ± 1 °C and 70 ± 5 % R.H.

Name of food plants	Sex	Hopper development period (Days)	Development of hoppers/ day (%)
Cynodon dactylon	Male	48.00–54.00 (50.83±0.63)	1.85–2.08 (1.99±0.04)
	Female	55.00–64.00 (58.30±0.88)	1.56–1.82 (1.75±0.07)
Paspalum distichum	Male	38.00–46.00 (43.00±1.20)	2.17–2.63 (2.34±0.09)
	Female	44.00–51.00 (47.50±1.50)	1.96–2.27 (2.11±0.08)
Sorghum vulgare	Male	45.00–51.00 (48.60±1.10)	1.96–2.22 (2.06±0.04)
	Female	70.00–76.00 (74.20±0.86)	1.31–1.43 (1.35±0.03)
Saccharum officinarum	Male	75.00–82.00 (79.30±0.37)	1.22–1.33 (1.26±0.06)
	Female	86.00–90.00 (88.50±0.23)	1.11–1.16 (1.14±0.02)
Seteria verticillata	Male	32.00–37.00 (35.80±0.53)	2.70–3.12 (2.81±0.08)
	Female	44.00–50.00 (46.30±0.78)	2.00–2.27 (2.17±0.07)
Seteria glauca	Male	40.00–50.00 (47.70±1.75)	2.00–2.50 (2.32±0.08)

Panicum psilopodium	**Female**	48.00–54.00 (50.90±0.89)	1.85–2.08 (2.01±0.06)
	Male	38.00–43.00 (39.90±0.69)	2.32–2.63 (2.54±0.09)
Cyperus rotundus	**Female**	46.00–54.00 (49.60±0.43)	1.85–2.17 (2.07±0.03)
	Male	30.00–36.00 (34.30±0.51)	2.77–3.33 (3.00±0.03)
Lactuca sativa	**Female**	38.00–44.00 (40.70±0.84)	2.27–2.63 (2.48±0.06)
	Male	52.00–57.00 (55.30±0.31)	1.75–1.92 (1.81±0.08)
Brassica campestris	**Female**	80.00–86.00 (83.70±0.68)	1.16–1.25 (1.19±0.06)
	Male	40.00–44.00 (41.70±0.22)	2.27–2.50 (2.40±0.07)
Brassica oleracea var. botrytis	**Female**	50.00–55.00 (52.10±0.43)	1.82–2.00 (1.92±0.09)
	Male	31.00–36.00 (33.20±0.54)	2.77–3.22 (3.03±0.03)
	Female	34.00–40.00 (38.40±0.98)	2.50–2.94 (2.64±0.05)

Mean ± S.E. is given parentheses

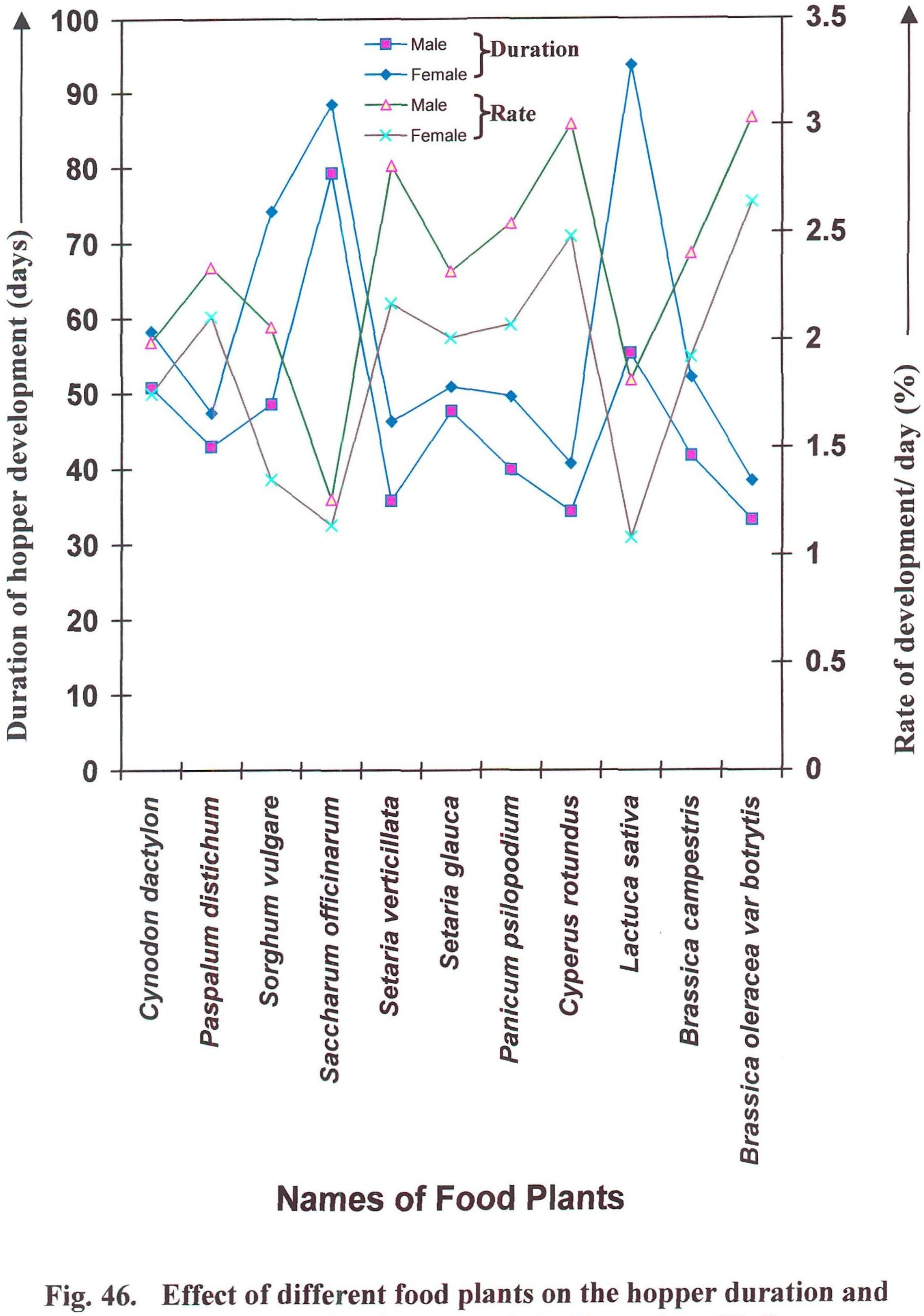


Fig. 46. **Effect of different food plants on the hopper duration and daily rate of development of *Acrida exaltata* Walk.**

various food plants has also been calculated. These observations were found to be extremely significant because of one fact that the food plants in the habitat are the biotic factor with differences in effectiveness. Presence or absence of such food plants will certainly determine the rate of hopper development with reference to sexes as well.

(b) Effect of food plants on the survivability of nymphal stages:

The significance of food plants for the survivability of nymphal stages or survival percentage along with hopper duration and growth index of *Acrida exaltata* was recorded. As evident from Table 14, thirteen food plants belonging to various families were used. The number and percentage of hoppers which attained adult stage and average hopper development period represent the total growth index. The growth index was calculated by taking percent hopper reaching adult stage as 'n' and the average developmental period as 'P'. the 'n/P' ratio shows that out of the thirteen plants, six have no bearing on the survival percentage. The highest average development (64.48%) of hopper reaching adult stage took place by feeding on *Seteria glauca* and the lowest (15.35%) on *Brassica oleracea* var *botrytis*. Other food plants have been arranged in accordance to their effectiveness. This gives a food preferential index within the habitat ad the abundance and scarcity of such food plants may determine the survival percentage and hopper duration alongwith growth index of the pest under study.

(c) Effect of food plants on adult survival and longevity:

The effect of various food plants on the pre–copulation, pre–oviposition, oviposition and post– oviposition periods and longevity of adults of *Acrida exaltata*, was studied with respect to adult. The results are shown in Table 14, 15 and Fig. 47

The longevity of adults was found to be different with *Seteria glauca* recorded as 55.2 days in males and 71.4 days in females. But the longevity of adults was maximum while feeding on *Seteria vericillata* as 62.1 days in males and 71.4 days in females. *Seteria glauca* mostly dominates the habitat, when hopper stages are in outbreaks.

Out of the six dominant food plants in the breeding area of the, two plant species namely *Seteria glauca* and *Cyperus rotundus* appear to be more preferred.

Table: 14. Effect of different food plants on the growth, survival, hopper duration and daily rate of development of *Acrida exaltata* Walk. reared at 35 ± 1 °C and 70 ± 5 % R.H.

(10 replicates)

Food plants provided	Sex	Percent hoppers becoming adult (n)		Average hopper duration (days) (p)	'Development' of hoppers/ day (%)	Growth index (n/ p)
Cynodon dactylon	Male	24.27	56.92	50.83	1.99	0.48
	Female	32.65		58.30	1.75	0.56
Paspalum distichum	Male	24.64	42.13	43.00	2.34	0.57
	Female	17.49		47.50	2.11	0.37
Sorghum vulgare	Male	22.49	46.16	48.60	2.06	0.46
	Female	23.67		74.20	1.35	0.32
Saccharum officinarum	Male	17.65	53.57	79.30	1.26	0.22
	Female	35.92		88.50	1.14	0.41
Seteria verticillata	Male	11.94	18.50	35.80	2.81	0.33
	Female	6.56		46.30	2.17	0.14
Seteria glauca	Male	25.49	64.48	47.70	2.32	0.53
	Female	38.99		50.90	2.01	0.77
Panicum psilopodium	Male	27.88	60.49	39.90	2.54	0.70
	Female	32.60		49.60	2.07	0.66

Cyperus rotundus	Male	14.81	34.64	34.30	3.00	0.43
	Female	19.83		40.70	2.48	0.49
Lactuca sativa	Male	16.56	28.16	55.30	1.81	0.15
	Female	11.60		93.70	1.08	0.12
Brassica campestris	Male	9.80	25.00	41.70	2.40	0.24
	Female	15.20		52.10	1.92	0.29
Brassica oleracea var. botrytis	Male	6.26	15.35	33.20	3.03	0.19
	Female	0.09		38.40	2.64	0.24

Table: 15. Effect of different food plants on the pre–oviposition, oviposition, post–oviposition periods, egg pods/ female and longevity of adults of *Acrida exaltata* Walk. reared at 35 ± 1 °C and 70 ± 5 % R.H.

(10 replicates, one pair in each replicates)

Food plants provided	Average pre – oviposition period (days ± S.E.)	Average oviposition period (days ± S.E.)	Average post – oviposition period (days ± S.E.)	Average egg–pods/ female (days ± S.E.)	Longevity of male (days ± S.E.)	Longevity of Female (days ± S.E.)
Cynodon dactylon	23.5 ± 2.12	18.9±1.47	5.3±1.61	3.3±0.15	40.5±5.47	48.4±2.97
Paspalum distichum	22.3±0.60	14.2±0.61	20.5±1.45	1.9±0.18	34.5±1.15	48.1±3.41
Sorghum vulgare	18.2±0.95	28.7±0.73	6.2±1.44	3.9±0.41	33.6±3.03	41.7±3.19
Saccharum officinarum	19.8±0.39	21.2±0.70	16.6±1.42	3.2±0.13	38.4±0.34	55.1±0.75
Seteria verticillata	27.6±1.29	24.9±1.59	23.6±1.39	0.6±0.16	62.1±5.53	71.0± 3.32
Seteria glauca	17.5±0.48	31.2±1.67	20.3±1.79	4.5±1.17	55.2±0.77	71.4±1.49
Panicum psilopodium	17.3±0.52	44.5±1.33	24.6±3.31	5.0±0.26	56.8±1.07	67.2±4.22
Cyperus rotundus	15.7±0.42	44.4±4.36	9.2±3.75	5.5±0.22	36.1±1.38	62.0±8.70
Lactuca sativa	17.5±0.62	16.8±1.33	12.3±0.90	0.6±0.16	27.1±1.99	40.2±1.38
Brassica campestris	13.5±0.40	18.1±1.35	12.4±1.39	2.4±0.16	18.8±0.96	21.9±1.88
Brassica oleracea var. botrytis	24.0±2.67	16.7±0.62	6.8±1.30	2.4±0.21	34.5±1.54	36.6±2.99

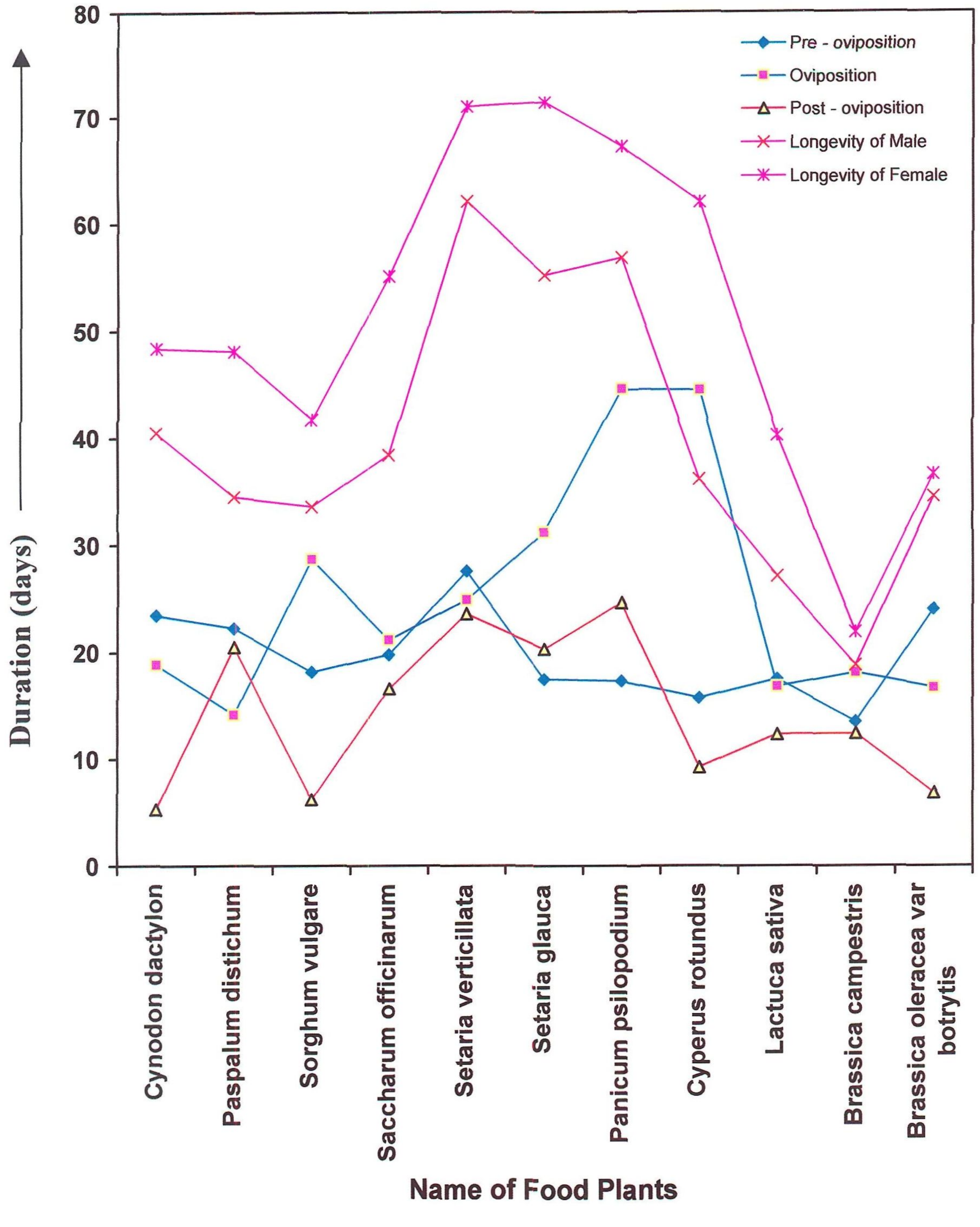


Fig. 47. Effect of different food plants on the pre–oviposition, oviposition and post – oviposition periods and longevity of adults of *Acrida exaltata* Walk.

(d) Effect of food plants on fecundity:

No worker has reported any effect of different plants on the fecundity of females of *Acrida exaltata*. In the present study, six food plants were tested in order to find out their effect on average fecundity. It was found to be 163.9 with *Cyperus rotundus* and 65.28 with *Saccharum officinarum* (Table 16). This may be due to the former being more nutritive than the latter.

(e) Food preferences in nymphs:

It is observed that out of the thirteen food plants tested, *Cyperus rotundus* was most preferred while *Saccharum officinarum* remain partly rejected. The maximum survival has been recorded while feeding on *Paspalum distichum*. These are quite useful, applied and hitherto unknown observations.

Table: 16. Effect of different food plants on the fecundity of females of *Acrida exaltata* Walk. at 35 ± 1 °C and 70 ± 5 % R.H.

(10 replicates, one pair in each replicates)

Food plants provided	No. of Females	Total egg – pods	Average egg–pods/ female (days ± S.E.) (a)	Total egg – pods laid	Average eggs/ egg – pod (± S.E.) (b)	Average fecundity (a×b)
Panicum psilopodium	25	125	5.0±0.26	3580	28.66±0.22	143.3
Cyperus rotundus	25	138	5.5±0.22	4110	29.81±0.26	163.9
Seteria glauca	25	113	4.5±1.17	3638	32.20±0.10	144.9
Sorghum vulgare	25	98	3.9±0.41	2198	22.43±0.11	87.47
Saccharum officinarum	25	80	3.2±0.13	1634	20.40±0.63	65.28
Cynodon dactylon	25	83	3.3±0.15	2502	30.18±0.16	99.59
Brassica oleracea var. *botrytis*	25	60	2.4±0.21	2053	34.28±0.91	82.27
Brassica campestris	25	60	2.4±0.16	1988	33.12±0.26	79.48

CHAPTER - IV

(D) MORPHOMETRICS AND GREGARIOUS BEHAVIOUR

Morphometrics are the measurements of morphological changes, during the life of an insect and the gregarious behaviour is the social aggregation among organisms. Generally there are ten species of grasshoppers, which have shown permanent innate characteristics of being a locust. A new concept was proposed by Rizvi (1985) regarding 'locusts in making' on the basis of some species of grasshoppers, which have been recently recorded having tendency of swarmlet formation. They show temporary phase of aggregational instinct and the pest under study belongs to this group. This means that there are certain ecological requirements for a solitary grasshopper to become a locust. Therefore, the morphometrics of hoppers was carried out on the body parts to obtain the rate of increase in various instars. The results are tabulated in Tables 6, 7. The adults of both sexes living under isolated and crowded conditions were measured, and about 21 indices of body parts were used and almost all of the used indices showed significant changes when subjected to crowded condition. These are indicative of definite instinct towards phase formation and gregariousness (Table 17–20). These observations are of great

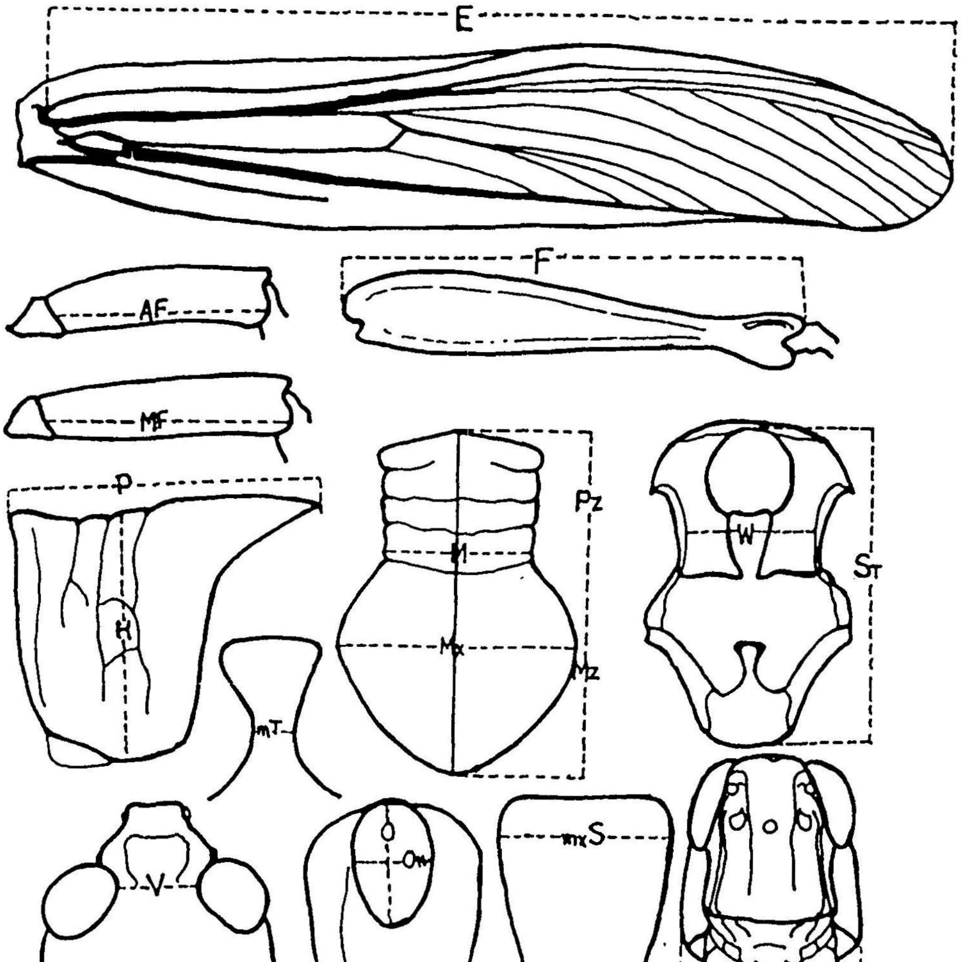


Fig. 48. Scheme of morphometrical measurements

significance in grasshopper's ecological and behavioural studies. The comparative account of body part measurements is given in Table 17–23.

The measurements of various body parts, mentioned below, with or without crowded conditions in both sexes were taken with the help of Vernier caliper supplied by Anti–Locust, London. Some measurements were also taken with a binocular and a micrometer eye piece. All measurements are in millimeters, unless otherwise stated. The observations are shown in Tables 17, 18 which clearly indicate that the tendency of polymorphism in grasshopper under study does exist.

All measurements were made on 30 males and 30 females each of isolated and crowded conditions.

1. **LENGTH OF BODY (B):** Distance from the anterior end of head to apex of subgenital plate in male and to apex of ovipositor in female.

2. **WIDTH OF BODY (b):** Widest part of thorax near the first abdominal segment.

3. **LENGTH OF ANTENNA (A):** The distance from the basal segment, the scape up to the terminal segment.

4. **WIDTH OF VERTEX BETWEEN THE EYES (V):** The shortest distance between the compound eyes at the vertex.

5. **VERTICAL DIAMETER OF EYE (O):** The maximum diameter of eye.

6. **HORIZONTAL DIAMETER OF EYE (Oh):** The minimum diameter of eye.

7. **MAXIMUM WIDTH OF HEAD (C):** The greatest width of the head in the genal region.

8. **LENGTH OF PRONOTUM (P):** The median pronotal carina.

9. **HEIGHT OF PRONOTUM (H):** The vertical distance between the lowest point of the lateral pronotal lobe and the level of the highest point on the median pronotal carina between the second and third sulci.

10. **MAXIMUM WIDTH OF PRONOTUM (Mx):** The greatest distance between the surfaces of the lateral pronotal lobes in the metazona.

11. **MINIMUM WIDTH OF PRONOTUM (Mp):** The minimum distance between the surfaces of the lateral pronotal lobes.

12. **LENGTH OF STERNUM (St):** The distance from the anterior suture of the mesosternum to the posterior edge of the first abdominal sternite.

13. **LENGTH OF ELYTRON (E):** The branching of costal (mediastinal) and the subcostal (anterior radial) veins to the apex of the elytron.

14. **WIDTH OF ELYTRON (e):** The distance between the two parallel lines touching the anterior and the posterior boundaries of the tegmen.

15. **SPAN OF BODY WITH ELYTRON (SE):** The distance from the apex of one elytron to the other, when both elytra are fully expanded.

16. **Length of wing (W):** The distance from the base of the costa to the apex of the wing.

17. **Width of wing (w):** The distance between the two parallel lines touching the anterior and the posterior boundaries of the wing when fully stretched.

18. **Length of anterior femur (AF):** The external surface of the femur, directed forwards, from the junction between the trochanter and the femur to the distal end of the latter.

19. **Length of middle femur (MF):** The anterior surface of the femur, from the suture between the trochanter and femur to the apex of the latter.

20. **Length of hind femur (F):** The external surface, as the maximum length from the base to the apex.

21. **Width of hind femur (f):** The maximum width from margin to margin.

Table: 17. Means, standard errors and standard deviations of crowded and isolated adults of *Acrida exaltata* Walk.

(30 replicates)

MALES

No.	Indices	Symbols	Mean and standard error		Standard deviation	
			Crowded	Isolated	Crowded	Isolated
1	Length of body	L	31.00±0.24	29.80±0.15	1.32	0.85
2	Width of body	b	03.58±0.03	03.50±0.09	0.19	0.47
3	Length of pronotum	P	04.93±0.04	04.87±0.05	0.23	0.26
4	Height of pronotum	H	02.68±0.03	02.60±0.02	0.15	0.12
5	Min. width of pronotum	Mp	02.21±0.02	02.15±0.02	0.11	0.10
6	Max. width of pronotum	Mx	02.67±0.03	02.57±0.02	0.17	0.13
7	Length of sternum	St	06.06±0.06	06.06±0.05	0.30	0.26
8	Span of body with elytron	SE	53.39±0.54	52.21±0.32	2.96	1.77
9	Length of elytron	E	25.33±0.28	24.61±0.18	1.55	0.99
10	Width of elytron	e	02.81±0.03	02.85±0.06	0.17	0.31
11	Length of wing	W	21.20±0.23	22.08±0.16	1.26	0.86
12	Width of wing	w	09.49±0.15	09.19±0.13	0.83	0.71
13	Length of anterior femur	AF	04.87±0.06	04.88±0.07	0.31	0.38
14	Length of middle femur	MF	06.06±0.06	05.93±0.06	0.36	0.31
15	Length of hind femur	F	18.79±0.30	18.16±0.24	1.68	1.31
16	Width of hind femur	f	01.31±0.02	01.25±0.01	0.11	0.06
17	Width of vertex between eyes	V	00.94±0.01	00.87±0.01	0.05	0.05
18	Vertical diameter of eye	O	02.58±0.03	02.51±0.02	0.14	0.12
19	Horizontal diameter of eye	Oh	01.26±0.01	01.22±0.01	0.05	0.07
20	Width of head	C	02.69±0.02	02.60±0.01	0.11	0.07
21	Length of antenna	A	11.25±0.15	10.87±10.10	0.80	0.56

Table: 18. Means, standard errors and standard deviations of crowded and isolated adults of *Acrida exaltata* Walk.

(30 replicates)

FEMALES

No.	Indices	Symbols	Mean and standard error		Standard deviation	
			Crowded	Isolated	Crowded	Isolated
1	Length of body	L	48.73±0.45	46.58±0.48	2.47	2.64
2	Width of body	b	06.01±0.07	05.94±0.08	0.37	0.42
3	Length of pronotum	P	07.96±0.09	07.61±0.11	0.49	0.62
4	Height of pronotum	H	04.37±0.06	04.33±0.11	0.32	0.24
5	Min. width of pronotum	Mp	03.76±0.04	03.59±0.03	0.20	0.18
6	Max. width of pronotum	Mx	04.34±0.05	04.14±0.05	0.29	0.29
7	Length of sternum	St	09.43±0.11	09.29±0.08	0.59	0.41
8	Span of body with elytron	SE	84.73±0.74	83.47±0.41	4.03	2.22
9	Length of elytron	E	40.31±0.38	39.77±0.22	2.07	1.22
10	Width of elytron	e	04.32±0.06	04.47±0.04	0.31	0.21
11	Length of wing	W	36.32±0.39	36.47±0.22	2.11	1.19
12	Width of wing	w	14.45±0.15	14.16±0.19	0.81	1.02
13	Length of anterior femur	AF	07.02±0.08	06.92±0.07	0.43	0.38
14	Length of middle femur	MF	09.33±0.11	09.11±0.12	0.59	0.68
15	Length of hind femur	F	29.86±0.35	28.44±0.31	1.91	1.71
16	Width of hind femur	f	02.10±0.003	02.14±0.03	0.19	0.15
17	Width of vertex between eyes	V	01.233±0.02	01.23±0.01	0.08	0.06
18	Vertical diameter of eye	O	03.22±0.04	03.27±0.03	0.20	0.14
19	Horizontal diameter of eye	Oh	01.53±0.01	01.60±0.02	0.07	0.08
20	Width of head	C	04.56±0.05	04.50±0.03	0.27	0.18
21	Length of antenna	A	14.45±0.25	15.04±0.21	1.38	1.15

Table: 19. Differences between means of body parts measurements for adults of *Acrida exaltata* Walk.

(30 replicates)

Males

No.	Indices	Symbols	Crowded – Isolated			
			Difference	t	d.f.	P
1	Length of body	L	+1.20	4.19	28	< 0.01
2	Width of body	b	+0.08	0.87	28	< 0.05
3	Length of pronotum	P	+0.06	0.95	28	< 0.05
4	Height of pronotum	H	+0.08	2.28	28	< 0.05
5	Min. width of pronotum	Mp	+0.06	2.21	28	< 0.05
6	Max. width of pronotum	Mx	+0.10	2.56	28	< 0.05
7	Length of sternum	St	+0.00	0.07	28	< 0.05
8	Span of body with elytron	SE	+1.18	1.88	28	< 0.05
9	Length of elytron	E	+0.72	2.15	28	< 0.05
10	Width of elytron	e	–0.04	0.62	28	< 0.05
11	Length of wing	W	–0.88	3.17	28	< 0.01
12	Width of wing	w	+0.30	1.51	28	< 0.05
13	Length of anterior femur	AF	–0.01	0.11	28	< 0.05
14	Length of middle femur	MF	+0.13	1.50	28	< 0.05
15	Length of hind femur	F	+0.63	1.62	28	< 0.05
16	Width of hind femur	f	+0.06	2.62	28	< 0.05
17	Width of vertex between eyes	V	+0.07	5.43	28	< 0.01
18	Vertical diameter of eye	O	+0.07	2.08	28	< 0.05
19	Horizontal diameter of eye	Oh	+0.04	2.55	28	< 0.02
20	Width of head	C	+0.09	3.78	28	< 0.05
21	Length of antenna	A	+0.37	2.08	28	< 0.05

Table: 20. Differences between means of body parts measurements for adults of *Acrida exaltata* Walk.

(30 replicates)

Females

No.	Indices	Symbols	Crowded – Isolated			
			Difference	t	d.f.	P
1	Length of body	L	+2.15	3.26	28	< 0.01
2	Width of body	b	+0.07	0.69	28	< 0.05
3	Length of pronotum	P	+0.35	2.43	28	< 0.05
4	Height of pronotum	H	+0.04	0.54	28	< 0.05
5	Min. width of pronotum	Mp	+0.17	2.75	28	< 0.02
6	Max. width of pronotum	Mx	+0.20	2.67	28	< 0.02
7	Length of sternum	St	+0.14	1.07	28	< 0.05
8	Span of body with elytron	SE	+1.26	1.50	28	< 0.05
9	Length of elytron	E	+0.54	1.23	28	< 0.05
10	Width of elytron	e	–0.15	2.20	28	< 0.05
11	Length of wing	W	–0.15	0.34	28	< 0.05
12	Width of wing	w	+0.29	1.22	28	< 0.05
13	Length of anterior femur	AF	+0.10	0.96	28	< 0.05
14	Length of middle femur	MF	+0.22	1.34	28	< 0.05
15	Length of hind femur	F	+1.42	3.04	28	< 0.05
16	Width of hind femur	f	–0.04	0.91	28	< 0.05
17	Width of vertex between eyes	V	+0.00	0.16	28	< 0.05
18	Vertical diameter of eye	O	–0.05	1.12	28	< 0.05
19	Horizontal diameter of eye	Oh	–0.07	3.61	28	< 0.01
20	Width of head	C	+0.06	1.01	28	< 0.05
21	Length of antenna	A	–0.59	1.80	28	< 0.05

Table: 21. Mean ratios in isolated and crowded conditions for adults of *Acrida exaltata* Walk.

(30 replicates)

S.No.	Ratios	Symbols	Mean and Standard error				Standard deviation			
			Males		Females		Males		Females	
			Crowded	Isolated	Crowded	Isolated	Crowded	Isolated	Crowded	Isolated
1	Length of Pronotum to Max. width of head	P/C	1.84±0.01	1.87±0.02	1.75±0.01	1.70±0.03	0.06	0.12	0.06	0.17
2	Length of elytron to Length of hind femur	E/F	1.33±0.01	1.36±0.02	1.35±0.01	1.40±0.02	0.06	0.11	0.08	0.09
3	Length of hind femur to Max. width of head	F/C	7.07±0.05	6.99±0.09	6.55±0.05	6.33±0.09	0.29	0.50	0.30	0.52
4	Length of hind femur to Length of pronotum	F/P	3.85±0.03	3.74±0.05	3.75±0.04	3.75±0.06	0.16	0.26	0.19	0.34
5	Vertical diameter of eye to Width of vertex	O/V	2.75±0.04	2.88±0.04	2.61±0.02	2.65±0.03	0.20	0.20	0.12	0.14
6	Length of hind femur to Width of vertex	F/V	20.59±0.41	20.90±0.35	24.25±0.25	23.40±0.44	2.27	1.94	1.34	2.39

Table: 22. Differences between means of ratios in isolated and crowded conditions for adults of *Acrida exaltata* Walk.

(30 replicates)

S.No.	Ratios	Symbols	Crowded males – Isolated males				Crowded females – Isolated females			
			Difference	t	d..f.	P	Difference	t	d..f.	P
1	Length of Pronotum to Max. width of head	P/C	–0.03	1.23	28	0.05	+0.05	4.52	28	<0.05
2	Length of elytron to Length of hind femur	E/F	–0.03	1.31	28	0.05	–0.05	1.28	28	<0.05
3	Length of hind femur to Max. width of head	F/C	+0.08	0.76	28	0.055	+0.22	5.01	28	<0.05
4	Length of hind femur to Length of pronotum	F/P	+0.11	1.98	28	0.05	–0.005	0.07	28	<0.05
5	Vertical diameter of eye to Width of vertex	O/V	–0.13	2.52	28	0.05	–0.04	5.19	28	<0.05
6	Length of hind femur to Width of vertex	F/V	–0.31	0.57	28	0.05	–0.86	4.70	28	<0.05

Table: 23. Differences between means of ratios in isolated and crowded conditions for adults of *Acrida exaltata* Walk.

(30 replicates)

S.No.	Ratios	Symbols	Crowded males – Crowded females				Isolated males – Isolated females			
			Difference	t	d..f.	P	Difference	t	d..f.	P
1	Length of Pronotum to Max. width of head	P/C	+0.09	6.00	28	0.01	+0.17	4.59	28	0.01
2	Length of elytron to Length of hind femur	E/F	−2.02	1.11	28	0.05	−0.04	1.60	28	0.05
3	Length of hind femur to Max. width of head	F/C	+0.52	4.60	28	0.01	+0.66	5.04	28	0.01
4	Length of hind femur to Length of pronotum	F/P	+0.10	2.22	28	0.05	−0.015	0.19	28	0.05
5	Vertical diameter of eye to Width of vertex	O/V	+0.14	3.33	28	0.01	+0.23	5.23	28	0.01
6	Length of hind femur to Width of vertex	F/V	−3.66	7.63	28	0.01	−2.50	4.46	28	0.01

(a) Isolation:

Most of the grasshoppers are solitary in nature but the grasshopper under study was found in semi–solitary condition and the measurements of the body parts (Tables, 17, 18) support the fact that they have a definite tendency towards gregariousness as supported by 21 indices taken as parameters.

The measurements of body parts of *Acrida exaltata* taking into account about 13 body parts and all five instars till they become adult along with rate of increase from instar to instar up to an adult stage, have given a complete morphometrical index of the biology of the pest (Tables 6, 7).

(b) Crowding:

The crowding has been recorded occasionally with a gregarious tendency, but the crowded conditions when created, certain morphometrical changes in the body parts of males and females as compared to isolated one were found significant (Tables 17, 18).

(c) Colour changes:

Visible colours of *Acrida exaltata* and *Phlaeoba infumata* are due to the pigments in the integument, which are mostly metallic or lustrous in appearance and many combinations of colours and their patterns are seen in these pests. Newly moulted hoppers and adults are whitish until pigments are formed though the range of colours in acridoids in general is less extensive. The colours are the shades of brown, grey and green, greenish, pinkish brown, red and reddish yellow or their combinations on various parts of the body. In these two pests the adult colourations are of interest as they show the change in the sexual status or an initial or primitive instinct of social aggregation which is expected in any case of over populous acridoids. It was found that the normal green shades are dominated by brown shades, either due to sexual maturation or the beginning of social aggregation. The third colour combination is the mixture of brown and green shades with reddish and pinkish appearances. These three colours are so different in one species that one confuses it to be a separate species. Theses changing colour patterns have an ecological bearing on the insect biology, which was hitherto unknown. The present observations are new in the sense that colour ecology is a behavioural index at all stages of biology of the pest. This account is for *Acrida exaltata*, which prefers dry biome but in case of *Phlaeoba infumata*, the colour combinations are of great importance and for the first time the colour changes in isolated as well as in crowded populations were found at variance. Even at sexual level the males exhibit a consistency in colour pattern but the females show four different colours starting from green and brownish and reddish shade with two intermediate darker combinations of the same shade and finally turning into dark brown with white stripe and reddish legs. These colours are prominently visible in the colour photos.

In one of the experiments the effect of the solar radiations on the colouration of the adults of *Acrida exaltata* and *Phlaeoba infumata* was studied. A significant change in the colour pattern was found to cause colour polymorphism. This should be investigated as a separate problem. The present observations may be attributed significantly to the behavioural pattern in a known species of solitary grasshoppers having tendency of gregarization or rather locusts like instinctive behaviour.

(d) Swarming:

The two species under study have shown occasional gregarization and clumpy distribution with temporary gregariousness (Rizvi, 1988 p.c.), which may be taken as a serious activity with some less well defined manifestations of gregarious behaviour. The present observations are occasional records and need elaborate field observations followed by laboratory experiments. But to assess the situation with special reference to these pests it is carefully noted that during outbreaks in the field and during large scale rearing, these two species have shown temporary swarming at various levels. The seriousness to this effect was taken up due to the changes in the aggregation behaviour, colour patterns in the adult and hopper activities in the field and conspicuous rearing behaviour in the laboratory. The differences in the size and activities are suggestive for gregarious species in making.

(e) Band formation:

In these two species, the gregarious females have a habit of laying eggs, not only in ecologically restricted spots, but also in dense group. It results in hoppers hatching from several parts finding themselves in close proximity to one another. These primary groupings are actually the beginning of band formation. Only on one occasion in both cases small band formation like locusts was recorded by Rizvi (1988 p.c.) and reported to the author but could not be ascertained later on because of unavoidable circumstances.

(f) Instinctive behaviour:

This is an important observation and suggestive in the sense that there are certain grasshoppers which can be treated as 'locust in making' (Rizvi, 1985). Similarly in these two acridoid pests, an instinct of gregarization in hoppers and gregarious egg – laying in adult females is obvious. Crowding affects the life of individuals, especially the changing flight behaviour, and on the basis of vigilant observations evidences may become available to accept that *Acrida exaltata* and *Phlaeoba infumata* are behaviourally instinctive towards occasional polymorphism. This is yet to be confirmed.

PART- II

Ecological studies on *Phlaeoba infumata* Brunner

CHAPTER – IV

OBSERVATIONS

PART –II: ECOLOGICAL STUDIES ON *PHLAEOBA INFUMATA* BRUNNER

(A) BIOLOGY

(i) LIFE – CYCLE IN THE LABORATORY:

(a) Adult:

The adult of *Phlaeoba infumata* (Fig. 8B) is medium sized. Head shorter than pronotum; frons slightly concave; fastigium of vertex long. Antenna flattened basally, extending beyond hind margin of pronotum, particularly in males. Pronotum with distinct lateral carinae, median carina interrupted by main transverse sulcus; hind wings hyaline, apex not or slightly infumate. Tegmina and hind wings extending as far as hind knees, or a little shorter. Male subgenital plate pointed. Male cercus slender, length four to five times diameter of base.

General colour reddish or olive brown, rather variable. A broad pale band extends from the fastigium of the vertex to the tips of the tegmina, lighter in males than in females. Antennae unicolourous or dark apically. Wings smoky apically, bluiush basally.

MEASUREMENTS OF ADULTS (mm):

	MALES	FEMALES
Length of the body	16.32 – 22.18 (20.86±0.72)	24.85 – 29.88 (29.20±0.08)
Length of pronotum	3.03 – 3.76 (3.69±0.08)	4.31 – 5.26 (5.19±0.07)
Length of tegmen	17.02 – 19.24 (19.08±0.18)	23.26 – 26.33 (24.92±0.26)
Length of hind femur	11.03 – 12.88 (12.42±0.41)	13.21 – 17.06 (16.48±0.44)

(b) Copulation:

The act of copulation is usually preceded by an elaborate courtship and some observations in this act of behaviour have been an addition to the knowledge, such as an intermittent movement of antennae and touching of last abdominal segments by the hind legs. The duration of copulation is long and the copulating pairs are not mobile and stationary in postures and this fact is important in control by using sprays. The time of copulation, duration and a typical acridian act of copulation are not different as to make a record except that the copulation lasts about 45 – 100 minutes (Table 1).

(c) Oviposition:

Oviposition is associated with female movements before actual egg–laying in connection searching, locating or testing for suitable conditions. The mechanism involved in oviposition is on a typical acridian pattern followed by digging, making false holes and finally the egg–laying process is done. The maximum time of oviposition is 135 minutes and the minimum 75 minutes with an average of 108.50±6.75 minutes (Table 1).

The structure of the egg–pod could be indicative of dependence on the oviposition habitat of the species particularly the soil structure. In this species it was found that the egg–pods in relation to soil surface and changes in the depth was in accordance to soil nature. The present findings are based on the number of egg–pods laid in three different soils and their comparative account is given in Table 2. This observation may be of some use from soil preference point of view and may help in finding the egg–laying sites of the species.

Other methods of oviposition:

This species also behaves like epidephic and epiphytic ovipositor and the change of oviposition behaviour may be attributed to super maturation of gonads and failure in finding suitable egg–laying sites. The hatching has never been recorded in those egg–pods which are laid outside the egg tube.

(d) Egg – pod and eggs:

The size of egg–pod is mainly determined by the number of egg–layings per female. The average number of egg–pods per female was found to be 3.28 ± 0.01(isolated condition) and 3.00 ± 0.13 (crowded condition) and the size of egg–pod laid earlier was longer than the egg–pod laid later. This may be due to the decrease in the number of eggs.

Table: 24. Measurements of egg, egg–pod and hatchling of *Phlaeoba infumata* Brunn.

(10 replicates)

INDICES	MEASUREMENTS (mm.)
Length of egg	5.40–5.90 (5.65±0.05)
Width of egg	1.30–1.50 (1.40±0.02)
Length of egg–pod	24.10–38.90 (29.40±1.50)
Width of egg–pod	3.40–4.10 (3.68±0..07)
Length of hatchling	62.00–65.00 (63.80±0.30)

Mean ± S.E. is given in parentheses.

The effects on the fecundity of the female due to isolated and crowded conditions, there has been an indication of behavioural changes due to group egg-laying. The average fecundity is also affected (Table 48).

The measurement of egg-pods and eggs of this species is given in Table 24. The Table 24 shows the actual length of egg – pod when the length of froth is deleted. The average number of eggs per egg-pod was found to be 19.65±0.98 (isolated condition) and 17.59±0.94 (crowded condition). This clearly indicates that the average number of eggs per egg-pod, laid by a female, differs considerably under isolated and crowded conditions. The average fecundity was also affected by the crowded condition (Table 48).

Since majority of acridoids of temperate climate spend most of the life-cycle in the egg stage, therefore, it is also true with this species which passes hot climate with a long dry spell as an egg stage. During this dormant period the eggs can withstand adverse condition of the environment. This suggests that an immediate attention be paid to the structure, properties and biological function of different types of egg-pods in relation to environment.

(e) Incubation and hatching:

The incubation period of *Phlaeoba infumata* was studied at different temperatures (Table 25) with reference to hatching period of eggs. The most preferred and productive temperature was found to be 35±1°C. The incubation and hatching was severely affected at 10±1°C and 45±1°C (Table 25). The relative humidity was not taken as the factor because it could not be maintained and remain interrupted due to unavoidable circumstances. The effects of isolated and crowded conditions on the viability of egg–pods and eggs was studied at 35±1°C with 70±5 % R.H in order to ascertain any effect of crowding on the number of egg–pods, number of viable egg–pods, fertility, and mortality (Table 44). It shows that the crowding does affect the number, viability and the developmental frequencies of the eggs. This behaviour behaviour is closely related to the established locust species.

Observations on the number of eggs hatched, percentage of hatching, total incubation period, per day development in relation to five different temperature exposures ranging from 10±1°C to 45±1°C, were made. The lowest percentage of eggs hatched (63.49%) was at 25±1°C and the average highest percentage of hatching went up to 86.67% at 35±1°C. In both cases the relative humidity was 70±5 %. Likewise the longest incubation period was

Table: 25. Effect of different temperatures on the incubation period and hatching of eggs of *Phlaeoba infumata* Brunn. At 70 ± 5% R.H.

Temperature (°C)	Total no. of egg–pods	Average no. of eggs/ pod	Total no. of egg counts	Incubation period (Days)	Development of eggs/ day (%)	No. of eggs hatched	Hatching percentage
10	25	18.80	470	-	-	No hatching	-
25	50	18.90	945	61.10	1.66	600	63.49
30	45	18.89	850	38.17	2.68	590	69.41
35	40	18.75	750	24.63	4.29	650	86.67
45	30	18.83	565	-	-	No hatching	-

(61.10 days) at 25±1°C and the shortest was (24.63 days) at 35±1°C. The development of eggs per day thus calculated was the slowest (1.66%) at 25±1°C and the fastest (4.29%) at 35±1°C. There was no hatching at 15±1°C and 45±1°C (Table 25).

Miscellaneous observations:

The egg mortality due to high temperature beyond 45±1°C and below 18°C has been recorded in the laboratory. The resistance offered by the eggs of this species was about 10 hours at –5°C leading to mortality as 20–25% and the eggs at 45°C up to 20 minutes could resist with 15–20% mortality. This environmental resistance power in the incubating eggs could be attributed to the hibernating behaviour at low temperatures and aestivation at high temperatures. The excess of watering to the egg–pods results in severe mortality to the developing eggs.

(f) Development of hoppers:

In this case also the word hopper or nymphal instar is being used to avoid confusing terminology for immature stages of the grasshopper under study before becoming an adult.

The development of hoppers consists of growth associated with periodic moults. The first instar hopper, immediately after the intermediate moult, is called a 'hatchling' (Fig. 18B). Its colour is creamy which becomes darker after little time. This colour is tinged with yellow shades.

The total growth of newly moulted hoppers was recorded by measuring the increase in the total body length and weight at the beginning of each instar, before feeding.

During hopper development an instar–wise weight of the hoppers and the rate of increase comes to be 6–9 mg in case of male and female first instar hoppers. In the male, having five instars, the rate of increase in the body weight was found to be highest in third instar as 2.21 while lowest in the fourth and fifth instar as 1.46. But female hoppers, with 6 instars, have shown the rate of increase in body weight highest in the third instar as 2.21 while lowest in the sixth instar as 1.98 (Table 26, Figs. 49, 50).

The first instar hopper measures 6.49 mm and goes up to 15.72 mm in fifth instar in male, while in case of female the first instar hopper measures 6.72 mm and reaches upto 18.12 mm in sixth instar before becoming adult.

Table: 26. Instar–wise weight of *Phlaeoba infumata* Brunn. and ratio of increase in various instars.

(10 replicates)

Instar	Males		Females	
	Weight (mg)	Ratio of increase	Weight (mg)	Ratio of increase
I	6.00–9.00 (7.80±0.32)	–	6.00–9.00 (7.80±1.03)	–
II	13.00–19.00 (16.20±0.70)	2.08	13.00–19.00 (16.20±0.70)	2.03
III	25.00–42.00 (35.80±1.81)	2.21	25.00–42.00 (35.80±1.81)	2.21
IV	36.00–73.00 (58.40±4.05)W^+	1.63	63.00–89.00 (76.80±3.03)	2.15
IV	35.00–69.00 (52.10±4.16)W^-	1.46	63.00–89.00 (76.80±3.03)	2.15
V*	59.00–136.00 (85.20±8.48)	1.46	98.00–126.00 (112.50±3.24)W^+	1.46
V**	50.00–125.00 (79.90±6.23)W^+	1.53	60.00–117.00 (90.10±5.47)W^-	1.17
VI*	–	–	160.00–297.00 (222.50±14.71)	1.98
VI**	89.00–137.00 (108.60±5.04)	1.36	115.00–225.00 (173.40±10.34)W^+	1.92
VII	–	–	229.00–300.00 (261.40±6.96)	1.51
Adult	113.00–195.00 (159.20±9.82)	1.47	251.00–423.00 (339.90±17.76)	1.30
Total	–	20.41	–	43.58

Mean ± S.E. is given in parentheses.

W^+ Reversal condition of alar rudiments.
W^- Non–Reversal condition of alar rudiments.
* Male with 5 hopper instars.
** Male with 6 hopper instars.

* Female with 6 hopper instars.
** Female with 7 hopper instars.
*** Female with 8 hopper instars.

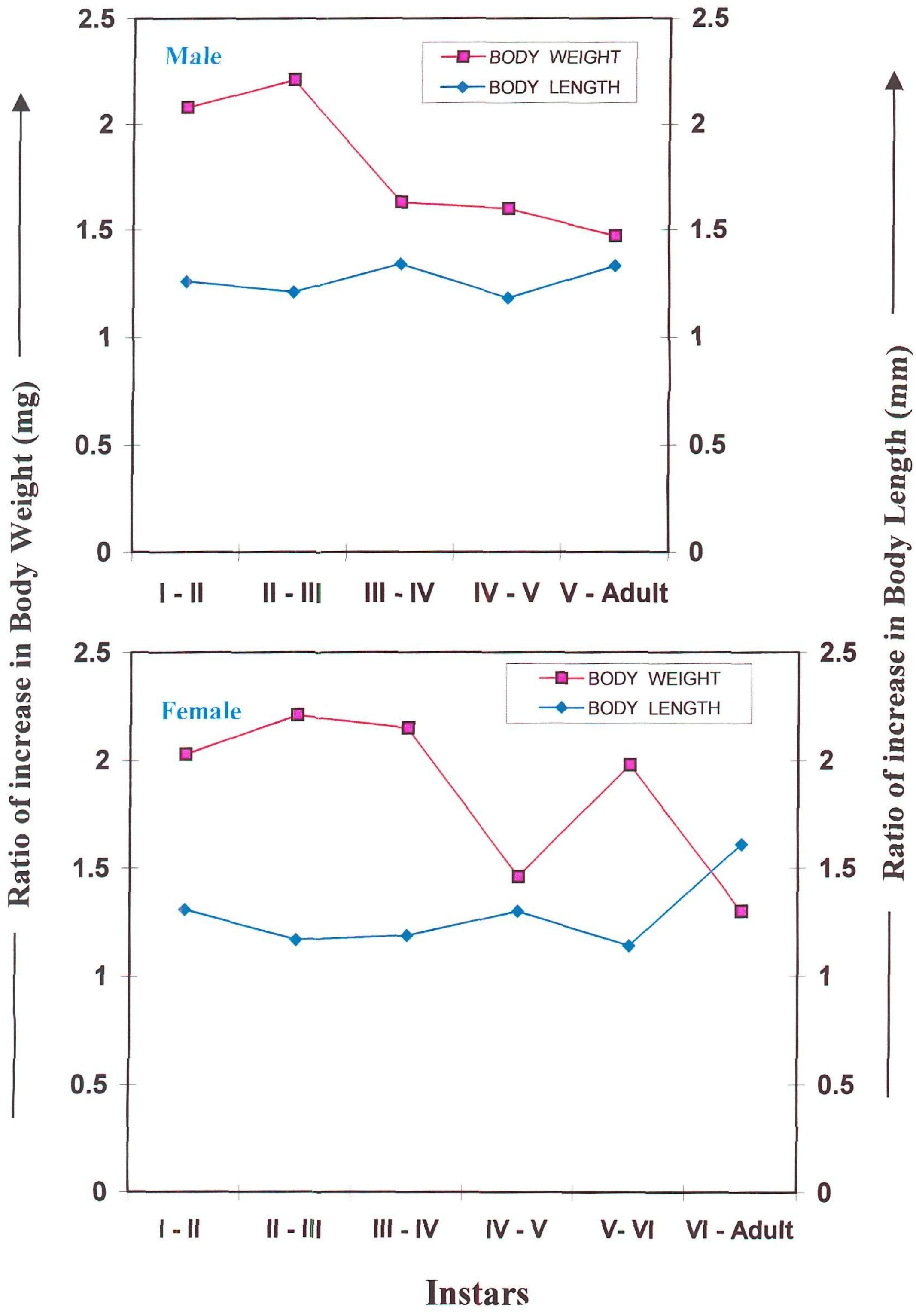


Fig. 49. Hopper growth of *Phlaeoba infumata* Brunn in length and weight

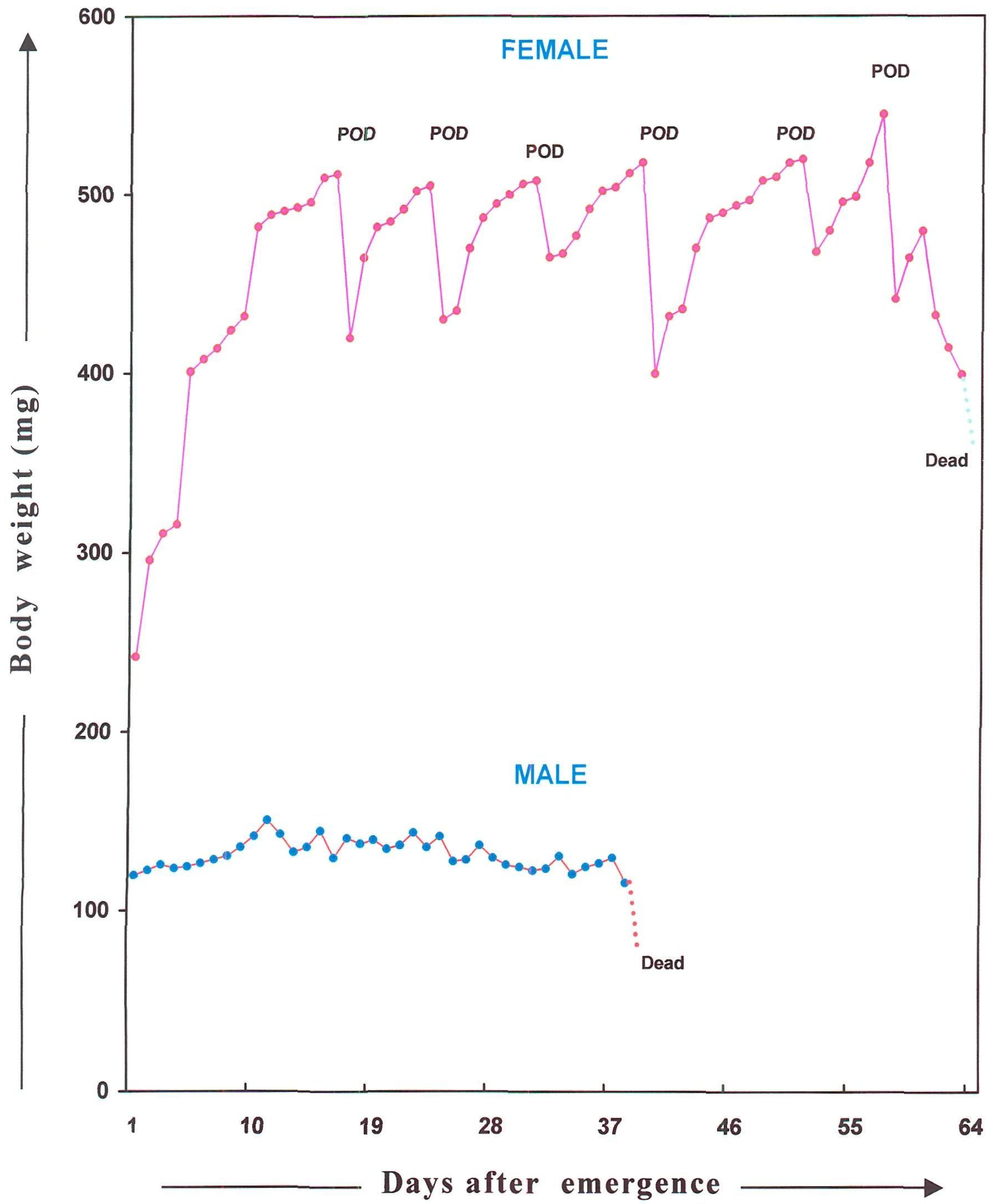


Fig.50. Daily variations in body weight of adults of *Phlaeoba infumata* Brunn. during their life span

In this species the entire life–cycle has shown the number of instar hoppers as different in two sexes and the female cycle is completed with an additional instar. The mean rate of increase of body length between instars in both sexes was calculated as 1.26 in males and 1.28 in females (Tables 27, 28).

The measurements of various body parts of the hoppers and the rate of increase in various instars in both sexes of this species were calculated. Thirteen body parts thus measured were the length and width of body; length of antenna; width of vertex between the eyes; vertical and horizontal diameter of eye; maximum width of head at genal level; length and height of pronotum; length of sternum; length of the anterior, middle and hind femur and width of hind femur.

These body parts were selected for measurement as they are considered most important by various workers in the field of acridology. These observations have been very useful in locust studies and now may be of immense use for future studies on polymorphism in solitary grasshoppers. Such body parts were measured in all stages of biology, starting from first instar hopper up to an adult in both sexes. The mean ratio of increase in size during development and growth were different in various body parts with variable magnitude.

Table: 27. Measurements (mm) of body parts of hoppers of *Phlaeoba infumata* Brunn. And ratio of increase in various instars.

(10 REPLICATES)

MALES

Indices	Symbols	Instars						Ratio of increase					
		I	II	III	IV	V	Adult	II/I	III/II	IV/III	V/IV	Ad/VI	Mean Ratio
Length of body	L	5.34–6.99 (6.49±0.15)	7.58–9.93 (8.19±0.21)	9.61–10.68 (9.91±0.10)	11.45–15 01 (13 30±0.40)	14.90–16.46 (15.72±0.16)	16.32–22.18 (20.86±0.72)	1.26	1.21	1.34	1.18	1.33	1.26
Length of pronotum	P	0.96–1.15 (1.08±0.02)	1.17–1.54 (1.34±0.03)	1.49–1.86 (1.70±0.04)	2.11–2.67 (2.33±0.06)	2.55–3.11 (2.87±0.06)	3.03–3.76 (3.69±0.08)	1.24	1.26	1.37	1.23	1.29	1.28
Height of pronotum	H	0.80 – 0.96 (0.87±0.02)	1.01 – 1.44 (1.20±0.04)	1.22 – 1.60 (1.39±0.04)	1.55 – 2.00 (1.82±0.05)	1.78 – 2.67 (2.24±0.08)	2.58 – 3.22 (3.15±0.08)	1.37	1.16	1.31	1.23	1.41	1.30
Length of sternum	St	1.28 – 1.38 (1.33±0.01)	1.70– 1.92 (1.80±0.02)	2.02 – 2.24 (2.14±0.02)	2.55–3.11 (2.77±0.06)	3.33–4.11 (3.53±0.07)	4.06 – 4.76 (4.62±0.09)	1.35	1.19	1.29	1.27	1.31	1.28
Length of anterior femur	AF	0.80 – 1.06 (0.91±0.02)	1.01 – 1.22 (1.12±0.02)	1.28 – 1.60 (1.32±0.02)	1.22 – 1.78 (1.96±0.04)	1.78 – 2.00 (1.92±0.02)	1.98 – 2.36 (2.34±0.07)	1.23	1.18	1.17	1.24	1.22	1.21
Length of middle femur	MF	1.01 – 1.28 (1.15±0.03)	1.12 – 1.33 (1.29±0.02)	1.49 – 1.76 (1.59±0.03)	1.78 – 2.22 (1.96±0 04)	2.11 – 2.44 (2.27±0.03)	3.11 – 3.72 (3.64±0.06)	1.12	1.23	1.23	1.16	1.60	1.27
Length of hind femur	F	2.61 – 3.73 (2.99±0.13)	3.84 – 4.69 (4.26±0.08)	4.89 – 5.67 (5.33±0.09)	5.89 – 7.45 (6.31±0.15)	7.78 – 9.01 (8.19±0.11)	11.03 – 12.88 (12.42±0.41)	1.42	1.23	1.18	1.30	1.52	1.33
Width of hind femur	f	0.55 – 0.74 (0.64±0.02)	0.80 – 0.90 (0.85±0.02)	1.01 – 1.22 (1.11±0.02)	1.22 – 1.55 (1.28±0.03)	1.33 – 1.66 (1.50±0.03)	1.61 – 1.88 (1.82±0.08)	1.33	1.31	1.15	1.17	1.21	1.23
Width of vertex between eyes	V	0.32 – 0.37 (0.34±0.01)	0.37 – 0.48 (0.43±0.01)	0.48– 0.53 (0.51±0.01)	0.54 – 0.55 (0.54±0.01)	0.66 – 0.89 (0.76±0.02)	0.86 – 1.06 (1.03±0.09)	1.26	1.19	1.06	1.41	1.36	1.26
Vertical diameter of eye	O	0.74 – 0.90 (0.85±0.02)	0.96 – 1.04 (0.99±0.01)	1.00 – 1.09 (1.04±0.01)	1.10 – 1.33 (1.16±0.02)	1.44 – 1.66 (1.55±0.03)	1.58 – 2.21 (2.15±0.07)	1.19	1.05	1.12	1.34	1.39	1.22
Horizontal diameter of eye	Oh	0.48 – 0.53 (0.50±0.01)	0.58 – 0.69 (0.64±0.01)	0.74 – 0.80 (0.76±0.01)	0.77 – 0.87 (0.81±0.02)	0.89 – 1.11 (1.00±0.03)	1.08 – 1.31 (1.28±0.08)	1.28	1.19	1.05	1.23	1.14	1.18
Max. width of head	C	1.22 – 1.28 (1.25±0.01)	1.33 – 1.44 (1.38±0.01)	1.49 – 1.60 (1.54±0.01)	1 66 – 1 89 (1.72±0.02)	2.00 – 2.33 (2.16±0.04)	2.31 – 2.76 (2.69±0.06)	1 10	1.12	1.12	1.26	1.25	1.17
Length of antenna	A	2.08 – 2.40 (2.20±0.03)	2.67 – 3.04 (2.85±0.04)	3.09 – 3.31 (3.20±0.02)	3 33 – 3.78 (3 66±0.05)	4.22 – 5.34 (4.81±0.15)	5.26 – 6.22 (6.20±0.07)	1.30	1.12	1.14	1.31	1.29	1.23

Table: 28. Measurements (mm) of body parts of hoppers of *Phlaeoba infumata* Brunn. and ratio of increase in various instars.

(10 REPLICATES)

FEMALES

Indices	Symbols	Instars							Ratio of increase						
		I	II	III	IV	V	VI	Adult	II/I	III/II	IV/III	V/IV	VI/V	Ad/VI	Mean Ratio
Length of body	L	6.05–7.04 (6.72±0.11)	8.06–9.18 (8.78±0.12)	9.87–10.68 (10.31±0.08)	11.68–14.01 (12.94±0.22)	14.46–17.24 (15.96±0.29)	17.35–18.92 (18.12±0.18)	24.85–29.88 (29.20±0.08)	1.26	1.21	1.26	1.23	1.14	1.61	1.28
Length of pronotum	P	1.01–1.22 (1.10±0.02)	1.28–1.60 (1.46±0.04)	1.60–1.97 (1.81±0.03)	2.00–2.55 (2.19±0.05)	2.55–2.78 (2.67±0.03)	3.44–4.00 (3.72±0.07)	4.31–5.26 (5.19±0.07)	1.24	1.26	1.21	1.22	1.40	1.40	1.29
Height of pronotum	H	0.80 – 0.96 (0.87±0.02)	1.12 – 2.30 (1.33±0.11)	1.33 – 1.44 (1.36±0.01)	1.66 – 1.78 (1.75±0.02)	2.11 – 2.22 (2.16±0.02)	2.78 – 3.56 (3.03±0.08)	3.30 – 4.53 (4.45±0.09)	1.37	1.16	1.29	1.23	1.40	1.47	1.32
Length of sternum	St	1.00 – 1.49 (1.26±0.01)	1.81 – 1.97 (1.89±0.02)	2.08 – 2.29 (2.16±0.03)	2.44–3.11 (2.84±0.02)	3.33–3.56 (3.46±0.03)	4.33–5.00 (4.60±0.08)	4.40–5.63 (5.59±0.09)	1.35	1.19	1.31	1.22	1.33	1.45	1.31
Length of anterior femur	AF	0.80 – 0.96 (0.88±0.02)	1.01 – 1.17 (1.07±0.02)	1.22 – 1.38 (1.30±0.02)	1.55 – 1.89 (1.69±0.04)	2.00 – 2.22 (2.08±0.03)	2.33 – 2.89 (2.61±0.05)	2.86 – 3.39 (3.33±0.07)	1.23	1.18	1.30	1.23	1.25	1.43	1.27
Length of middle femur	MF	0.90 – 1.17 (1.06±0.03)	1.22 – 1.44 (1.31±0.03)	1.49 – 1.76 (1.59±0.02)	1.66 – 2.22 (2.01±0.06)	2.33 – 2.55 (2.44±0.02)	2.78 – 3.33 (2.61±0.05)	3.61 – 4.95 (4.87±0.06)	1.12	1.23	1.26	1.21	1.25	1.60	1.28
Length of hind femur	F	2.77 – 3.57 (3.10±0.09)	4.00 – 4.78 (4.42±0.10)	4.96 – 5.87 (5.41±0.08)	6.56 – 7.23 (6.92±0.09)	8.01 – 8.34 (8.17±0.04)	10.01 – 10.79 (10.34±0.09)	13.21 – 17.06 (16.48±0.44)	1.42	1.25	1.28	1.18	1.27	1.59	1.33
Width of hind femur	f	0.55 – 0.85 (0.70±0.03)	0.90 – 0.96 (0.93±0.01)	1.01 – 1.17 (1.10±0.02)	1.22 – 1.33 (1.28±0.02)	1.55 – 1.89 (1.70±0.03)	1.89 – 2.22 (2.05±0.04)	2.71 – 3.33 (3.14±0.06)	1.33	1.31	1.16	1.33	1.21	1.48	1.30
Width of vertex between eyes	V	0.32 – 0.37 (0.34±0.01)	0.37 – 0.48 (0.43±0.01)	0.52 – 0.58 (0.53±0.01)	0.65 – 0.68 (0.66±0.01)	0.77 – 0.89 (0.80±0.02)	0.89 – 1.00 (0.91±0.01)	0.81 – 1.14 (1.11±0.07)	1.26	1.19	1.25	1.21	1.14	1.32	1.23
Vertical diameter of eye	O	0.74 – 0.85 (0.79±0.02)	0.90 – 1.12 (1.03±0.03)	1.06 – 1.17 (1.15±0.01)	1.11 – 1.33 (1.24±0.03)	1.22 – 1.44 (1.33±0.02)	1.44 – 1.55 (1.52±0.01)	1.38 – 1.91 (1.89±0.08)	1.19	1.05	1.08	1.07	1.14	1.39	1.15
Horizontal diameter of eye	Oh	0.48 – 0.58 (0.53±0.01)	0.64 – 0.69 (0.67±0.01)	0.74 – 0.80 (0.76±0.01)	0.77 – 1.00 (0.87±0.02)	0.89 – 1.00 (0.96±0.02)	1.00 – 1.22 (1.08±0.03)	1.14 – 1.28 (1.24±0.07)	1.28	1.19	1.14	1.10	1.13	1.21	1.17
Max. width of head	C	1.22 – 1.28 (1.25±0.01)	1.33 – 1.49 (1.40±0.02)	1.54 – 1.76 (1.61±0.02)	1.78 – 2.11 (1.91±0.05)	2.22 – 2.44 (2.30±0.03)	2.78 – 3.00 (2.87±0.03)	3.22 – 3.98 (3.94±0.09)	1.10	1.12	1.19	1.20	1.25	1.37	1.20
Length of antenna	A	2.29 – 2.67 (2.45±0.05)	2.72 – 3.04 (2.87±0.04)	3.20 – 3.47 (3.35±0.03)	3.33 – 4.22 (3.60±0.08)	3.89 – 4.22 (4.02±0.04)	4.56 – 5.56 (5.05±0.11)	6.06 – 6.98 (6.90±0.08)	1.30	1.12	1.07	1.12	1.26	1.31	1.19

Such observations may provide a measuring scale of the species in particular and with other grasshoppers in general. The Tables 27 & 28 are self explanatory. It is to be noted that the mean rate of increase in case of males was highest in the length of hind femur (1.33) and lowest in the width of head (1.17), while in case of females it was highest in the length of hind femur (1.33) and lowest in the vertical diameter of eye (1.15). These measurements and their ratios may be of great biological utilization especially during polymorphic behaviour of those grasshoppers, which show occasional gregarization and social behaviour.

The development of tegmina and wings in acridoids has already been considered as a special feature for distinguishing between hopper instars. In the first instar hopper, the lower posterior angles of the mesonotum and the metanotum donot show any differentiation but in the second instar they become somewhat extended and punctured, and in the subsequent instars they appear as rounded–triangular lobes, directed obliquely downward with distinct traces of longitudinal ridges, which are tracheae, later to become axillary vein; their number in the hind wings of *Acrida exaltata* increases at each moult. The striking change occurs in the alar rudiments in the second instar and both pairs of rudiments turned on their axes so that the outer surfaces become the inner and the rudiments of the tegmina (attached to the mesonotum become covered by those of the wings, both lying dorsally and directed obliquely upwards). The reversal of the alar rudiments thus divided the hopper instar into two distinct groups. The instar in which the reversal occurs, varies according to the total number of instars and may differ in two sexes of the same species. In case of *Phlaeoba infumata*, the instars pass through different number of instars in the two sexes. In this case, rudiments are lateral up to third instar and rudiments reversed in the fourth and fifth instars before becoming adult. This is in case of males (having five hopper instars), while in females rudiments remain lateral up to the fourth instar and rudiments reversed in fifth and sixth instars before becoming adult. The reversal of alar rudiments in male and female of this species having different numbers of instars is illustrated in Figs. 56, 57 and Table 29.

On the basis of hopper instars in which the reversal of alar rudiments occurs differently in the two sexes, which may be of significance in the male and female distinctive mature stages.

The sexual differentiation of the terminal abdominal segment and of the external genitalia in different instars, as well as in the two sexes, can be distinguished in hoppers without any difficulty. The changes in external genitalia during the development of *Phlaeoba infumata*are shown in Figs. 58, 59. A distinctive change is

Table: 29. Hopper instars of *Phlaeoba infumata* in which the reversal of alar rudiments occurs.

(L, rudiments lateral, R, rudiments reversed, Ad, adult)

Sex	Instars							
	I	II	III	IV	V	VI	VII	Ad
Males having 5 instars	L	L	L	R	R	Ad		
Males having 6 instars	L	L	L	L	R	R	Ad	
Females having 6 instars	L	L	L	L	R	R	Ad	
Females having 7 instars	L	L	L	L	L	R	R	Ad

found at the stage of final instar in two sexes. The female has six instars in which both upper and lower valves are longer than paraprocts, while in case of male there are five instars, where subgenital plate is elongate–parabolic, much longer than paraprocts. The descriptive and diagrammatic sketches of terminal abdominal segments and external genitalia given in Figs. 58, 59 are self explanatory. A comparative description on the changes of the terminal abdominal segments during the development in both sexes is as follows:

Stage	Male	Female
I	Subgenital plate semi–circularly excised at apex, with short obtuse lobes covering only base of paraprocts.	Upper ovipositor valves short, triangular sub– acute, separated by a broader excision. Lower ovipositor valves represented by a transverse fold (distinct only towards end of the instar) at bases of upper valves.
II	Subgenital plate narrowed to apex which has a shallow excision and reaches middle	Upper ovipositor valves longer, acute, separated by a broader excision. Lower

	of paraprocts.	valves broadly triangular, separated by acute angular excision.
III	Subgenital plate broadly parabolic apex, reaching beyond middle of paraprocts.	Upper ovipositor valves broader, separated by a broader excision. Lower valves almost as long as upper.
IV	Subgenital plate with narrowly parabolic apex reaching almost to apex of paraprocts.	Upper ovipositor valves longer, triangular, acute, separated by a broader excision. Lower valves as long as upper
V	Subgenital plate elongate–parabolic, much longer than paraprocts.	Left and right ovipositor valves separated along its middle line. Upper valve shorter than paraprocts.
VI	Subgenital plate much elongate parabolic pointed at the apex	Upper ovipositor valves longer than paraprocts and lower valve smaller than paraprocts.

VII	----	Both upper and lower valves longer than paraprocts.
Adult	Aedeagus is formed.	Upper and lower valves sclerotised and well–developed ovipositor is formed.

During normal moulting from hoper to hopper, it was interesting to note that some impartial and incomplete moulting do occur, especially during over-crowding, leading to various deformities but having no adverse effect on the reproductive potential.

The variation in the number of hopper instars between species or in a single species with special reference to sex, though, have been reported in various cases but in this species the said phenomenon is a conspicuous one. The male having 5–6 instars and the female having 5–7 instars and their number are always found variable even at a constant temperature and humidity (Table 30). The average total hopper duration, reduces or increases, indicates the number of instars. In this species male individual cycle with five instar hoppers is completed in 46.13±1.36 days while female individual cycle with six instar hoppers is completed in 55.87±1.47 days (average hopper duration). The hopper duration can be attributed to the number of instars in the cycle. This is also a new observation in acridoid biology.

Variation in the number of hopper instars:

Variation in hopper instar number within the species is of an ecological interest and has been regarded as an abnormality, which

Table: 30. ***Phlaeoba infumata*** **Brunn. : Period taken by isolated hoppers for development reared at 35±1 °C on grass,** ***Cynodon dactylon*** **Pers. leaves.**

(30 REPLICATES)

AVERAGE HOPPER DURATION (DAYS)	MALES WITH 5 INSTARS	MALES WITH 6 INSTARS	FEMALES WITH 6 INSTARS	FEMALES WITH 7 INSTARS
I INSTAR	6–10 (7.70±0.23)	6–17 (8.70±0.46)	6–10 (7.90±0.25)	6–10 (7.90±0.26)
II INSTAR	6–10 (7.47±0.24)	5–13 (8.43±0.37)	4–11 (7.63±0.33)	6–10 (7.50±0.22)
III INSTAR	6–9 (7.37±0.21)	5–13 (8.57±0.39)	6–10 (7.90±0.26)	6–14 (8.67±0.35)
IV INSTAR	7–11 (8.70±0.21)	7–15 (9.73±0.45)	7–12 (8.80±0.29)	7–14 (9.30±0.31)
V INSTAR	7–16 (9.77±0.38)	7–15 (9.03±0.36)	8–13 (9.17±0.25)	8–16 (11.17±0.53)
VI INSTAR	–	7–15 (9.73±0.41)	8–13 (9.90±0.31)	8–13 (9.33±0.42)
VII INSTAR	–	–	–	8–19 (10.50±0.49)
AVERAGE TOTAL HOPPER DURATION (DAYS)	35–50 (46.13±1.36)	56–82 (70.16±1.51)	42–62 (55.87±1.47)	67–9 (79.33±1.24)
DEVELOPMENT OF HOPPERS/ DAY (%)	2.00–2.85 (2.19±0.07)	1.21–1.51 (1.44±0.03)	1.61–2.38 (1.80±0.05)	1.11–1.49 (1.27±0.02)

Mean ± S.E. is given in parentheses.

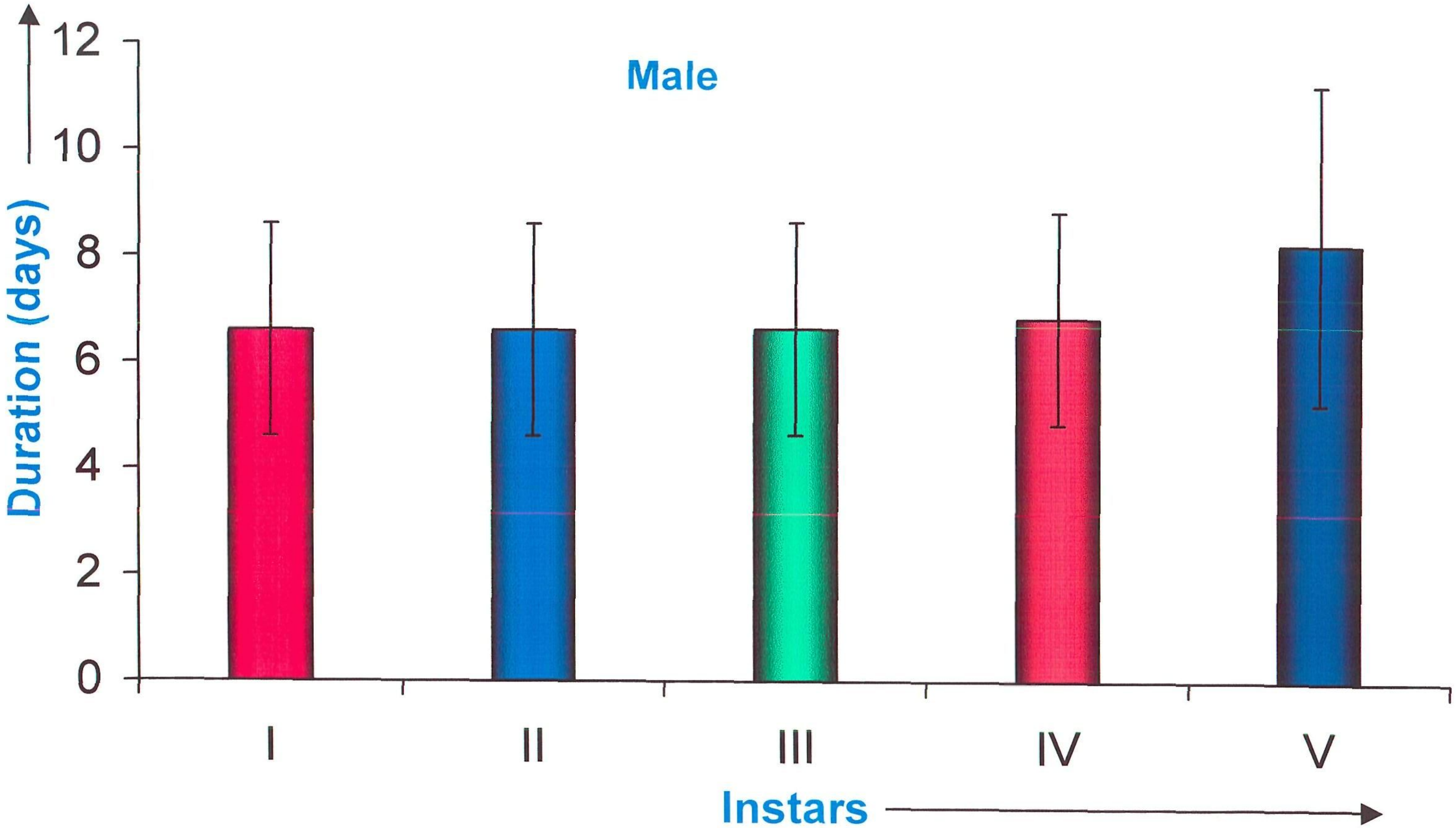


FIG. 51. NYMPHAL DURATION AND RANGE VARIABLES OF *Phlaeoba infumata* BRUNN.

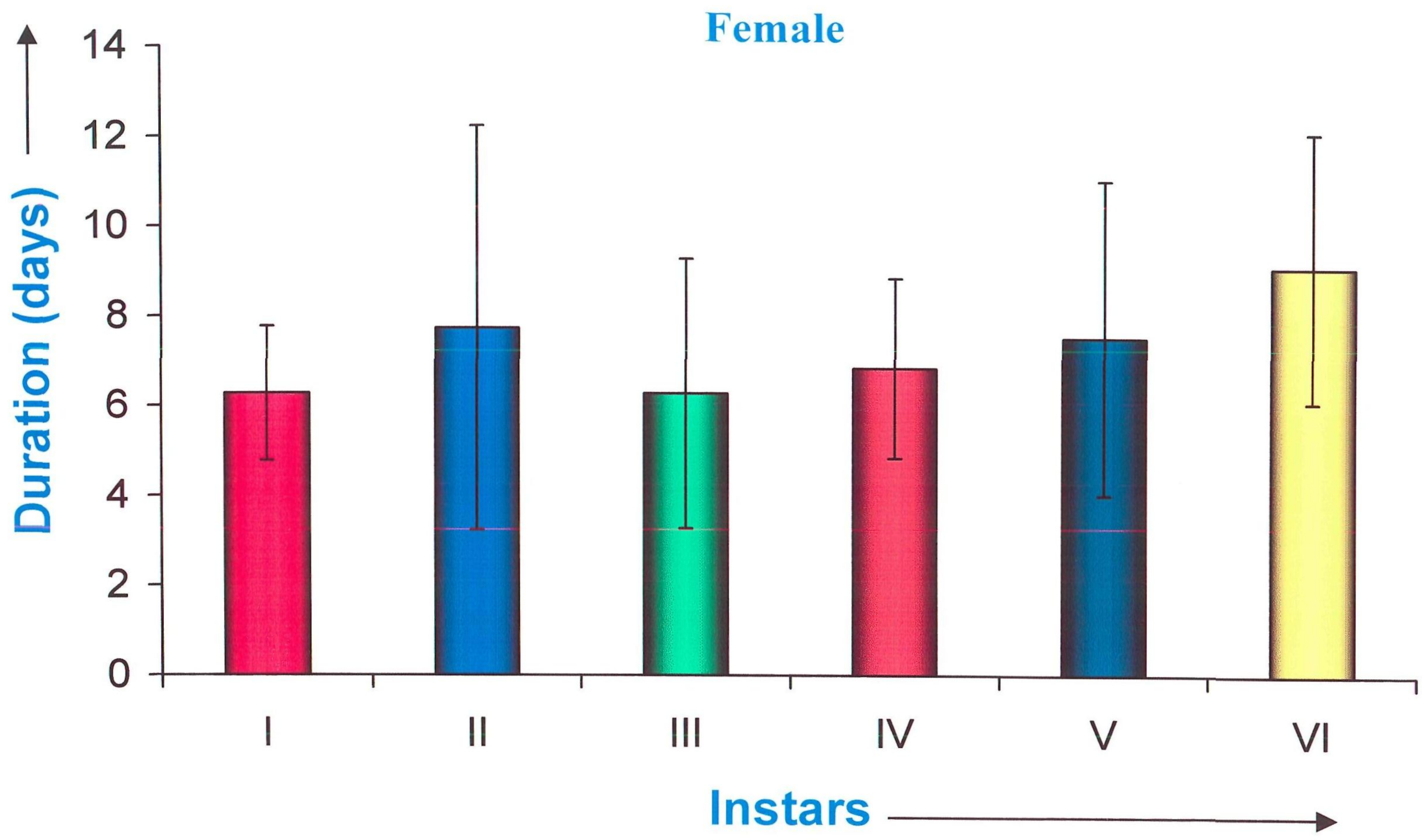


FIG. 52 . NYMPHAL DURATION AND RANGE VARIABLES OF *Phlaeoba infumata* BRUNN.

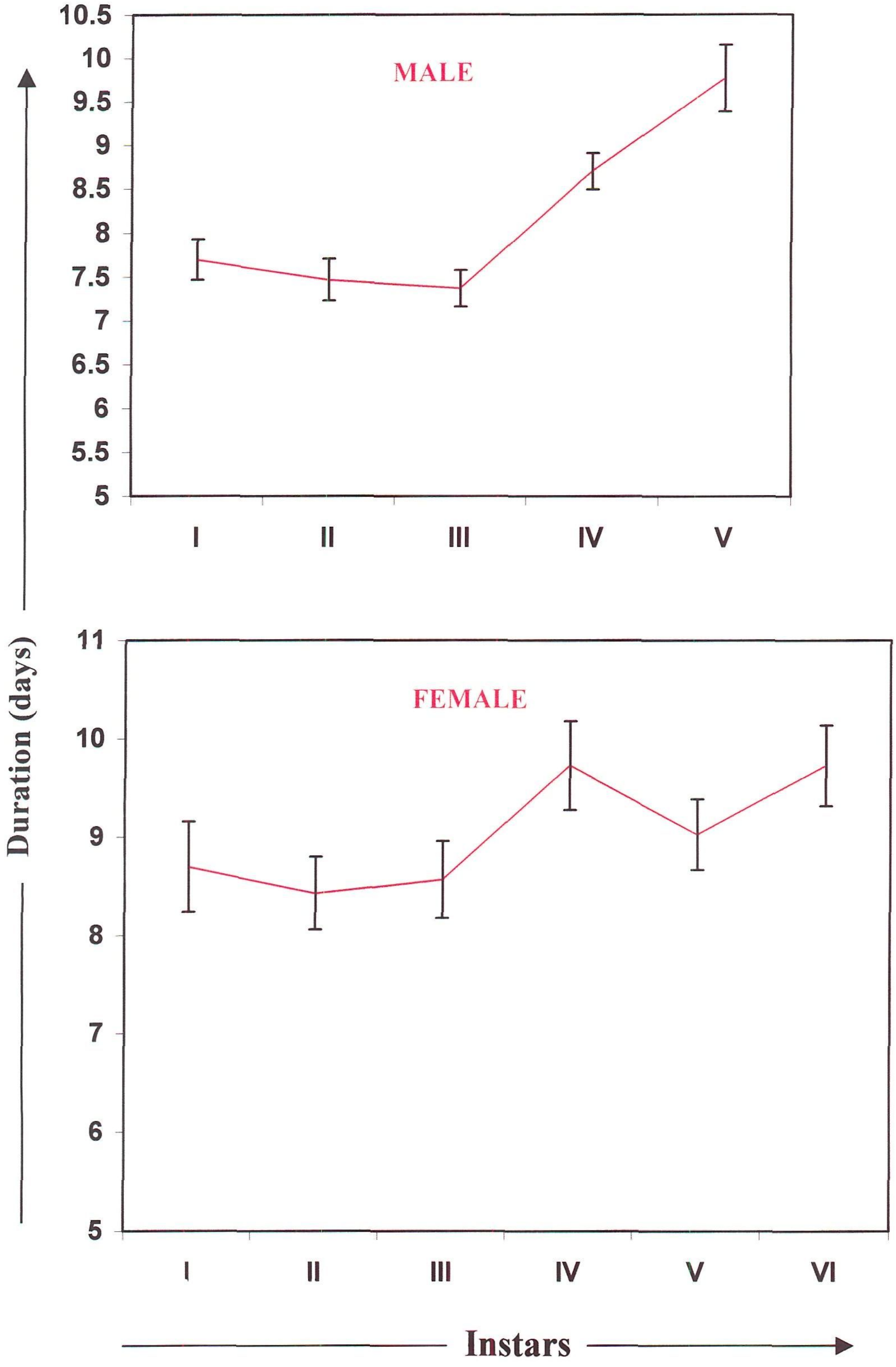
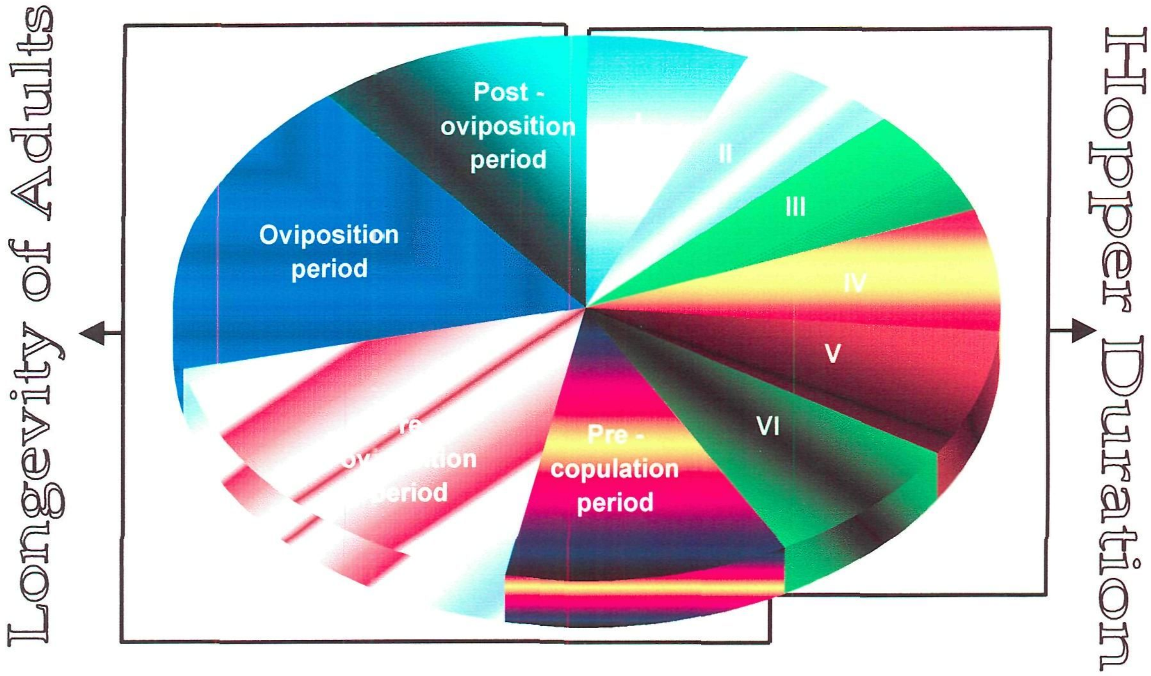
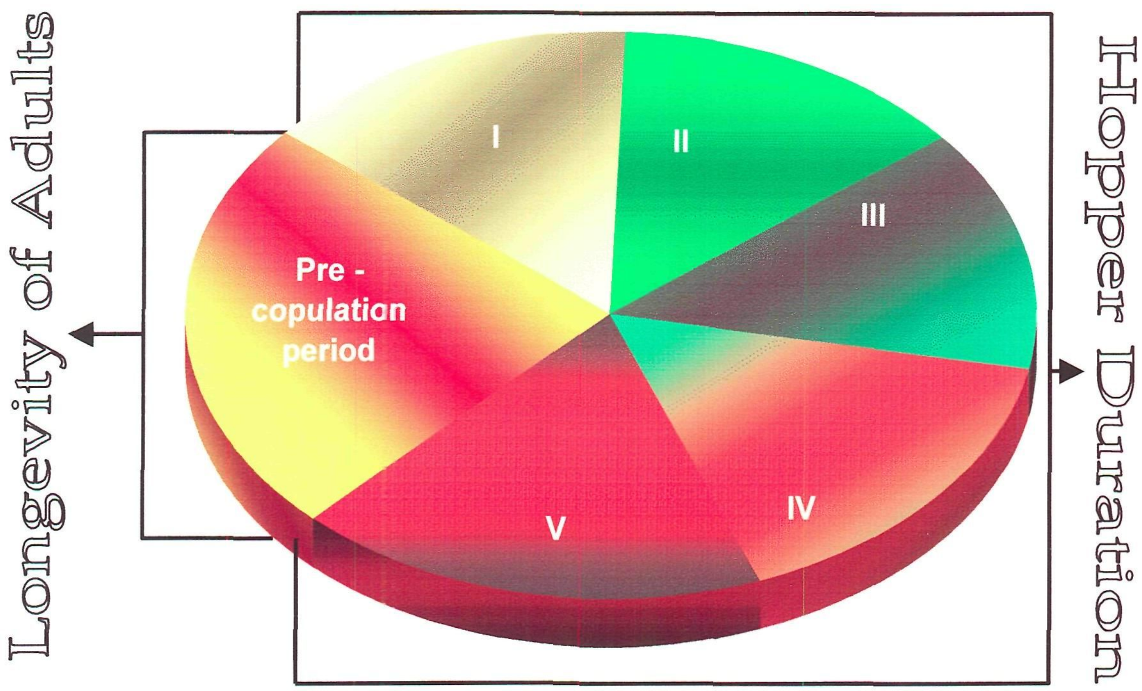


Fig.53. Nymphal duration of *Phlaeoba infumata* Brunn.



FEMALE



MALE

Fig:54 . Diagrammatic presentation of biological indices of *Phlaeoba infumata* Brunn.

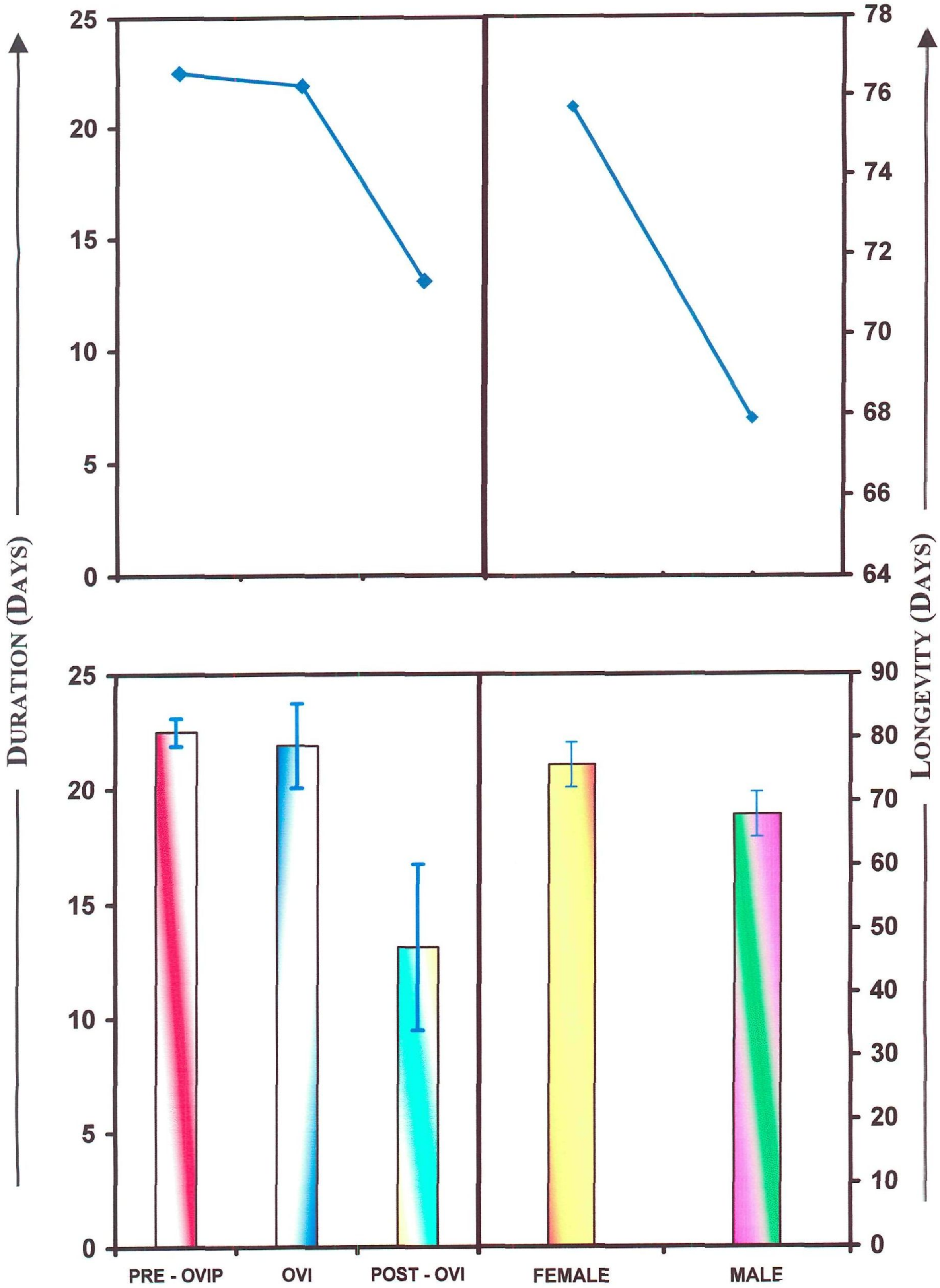


Fig. 55. Pre–oviposition, Oviposition and Post–oviposition periods and longevity of adults of *Phlaeoba infumata* Brunn.

is not true in view of the present observations. On comparing laboratory population with that of field populations in terms of percentage of instar hoppers, it was found that the laboratory population in this species mostly consists of 80%, five instars hoppers in males and six instars hoppers in females but in the field populations the number of instar hoppers were mostly variable which can be attributed to controlled as well as uncontrolled conditions. An additional instar hopper can also be attributed to an ecological adaptation in response to the abrupt change in climatic condition and food searching behaviour.

DESCRIPTION OF HOPPER INSTARS:

First instar hopper:

The freshly hatched nymphs are yellowish in colour but after sometime attain brownish stains and certain spots appear on the anterior part of the body. They measure 6.46 mm in average body length in males and 6.72 mm in females. Antennae with 8 segments (Figs 61, 69).

Second instar hopper:

The body of the second instar hopper becomes brownish with dark brown spots on the anterior side and less on the abdomen. It measures 8.19 mm in average body length in males and 8.78 mm in females. Antennae with 10– 12 segments (Figs. 62, 70)

Third instar hopper:

Similar to second instar except that the colour is variable dark brown, muddy, coppery green or reddish. In some cases brownish body with green patches on the head. Average body length measures 9.91 mm in males and 10.31 mm in females. Antennae with 12–14 segments (Figs. 63, 71).

Fourth instar hopper:

Body colour varies from dull brown to green with black dots; wing buds reversed in males. Average body length measures 13.30 mm in males and 12.26 mm in females. Antennae with 14 segments (Figs. 64, 72).

Fifth instar hopper:

General body colour varies from brownish to greenish. Wing buds reversed in males and females. Average body length measures 15.72 mm in males and 15.96 mm in females. Antennae with 15 – 16 segments. Males becoming adult following the moult at the end of this instar (Figs. 65, 73).

Sixth instar hopper:

In case of males there are only five instar hoppers but whenever there is an additional sixth instar, it can be identified with 17 – 18 antennal segments; in case of females there are usually six instar hoppers and the average body length measures 18.12 mm. (Figs. 66, 74).

Seventh instar hopper (females only):

In case of females there are usually six instar hoppers but if there is an additional seventh instar, it can be recognized by having 18–20 antennal segments. (Figs. 67, 75).

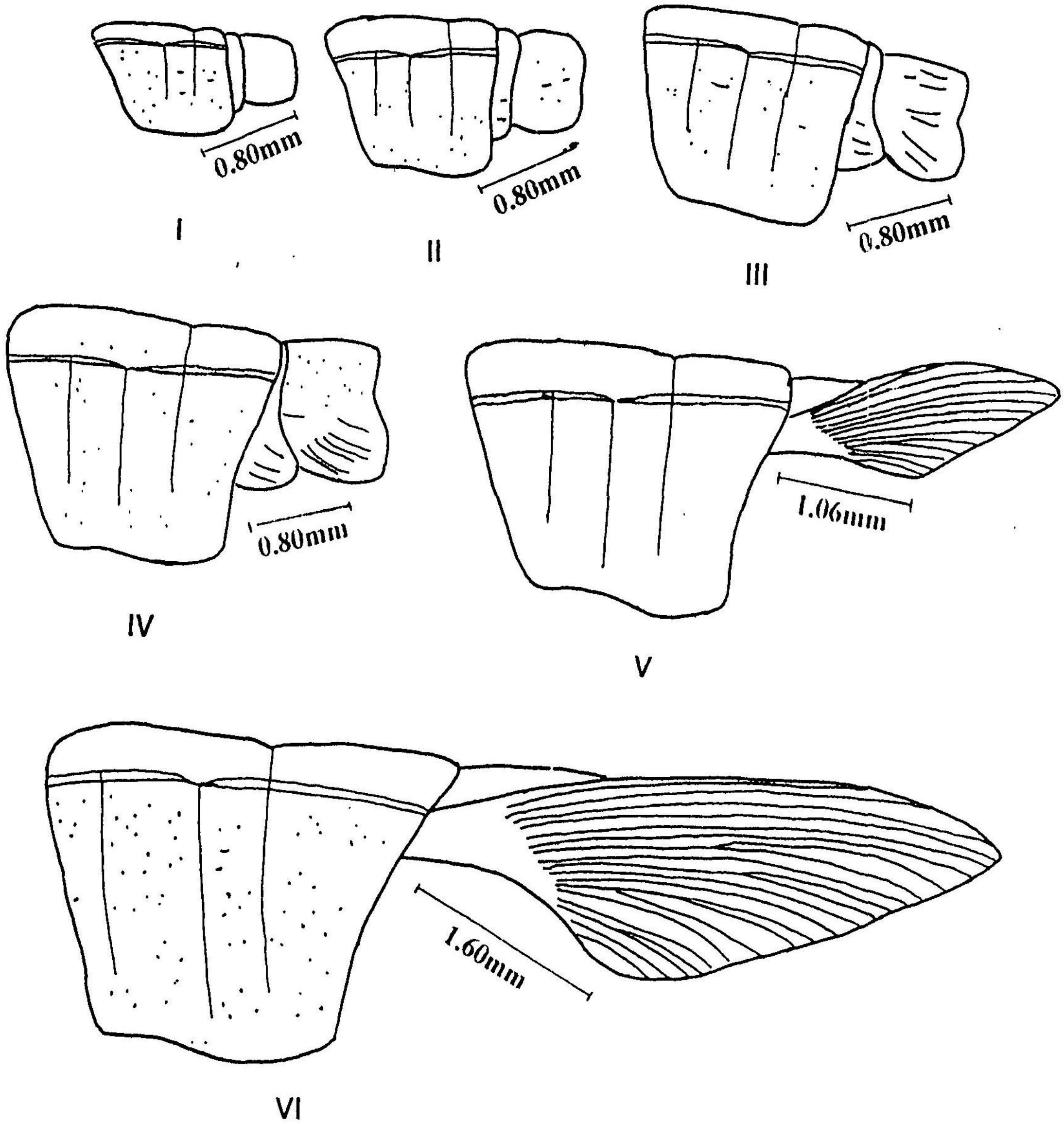


FIG.56. *Phlaeoba infumata* Brunn., growth of wing rudiments in male

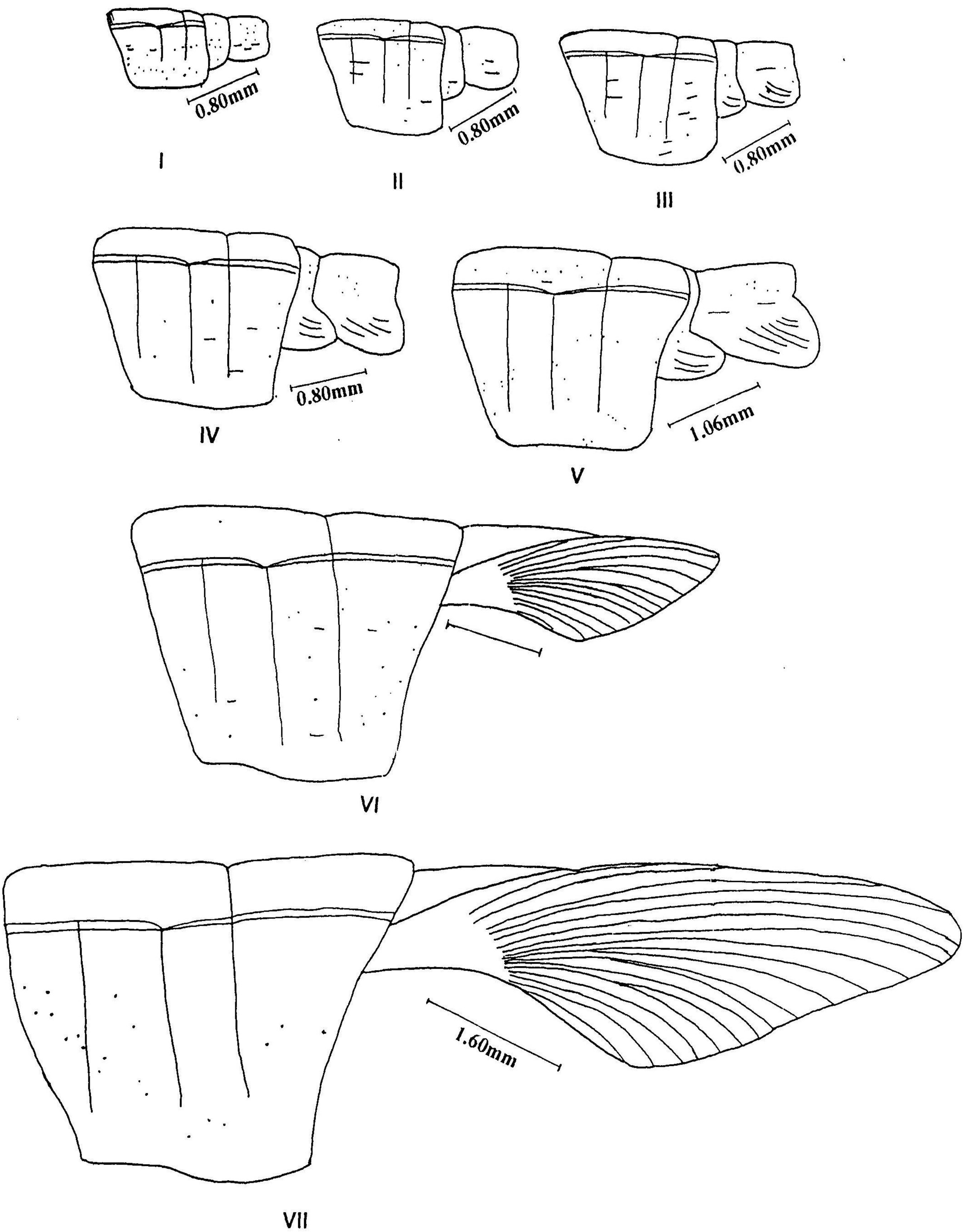


FIG.57. ***Phlaeoba infumata*** **Brunn., growth of wing rudiments in female**

SG, SUBGENITAL PLATE
P, PARAPROCT

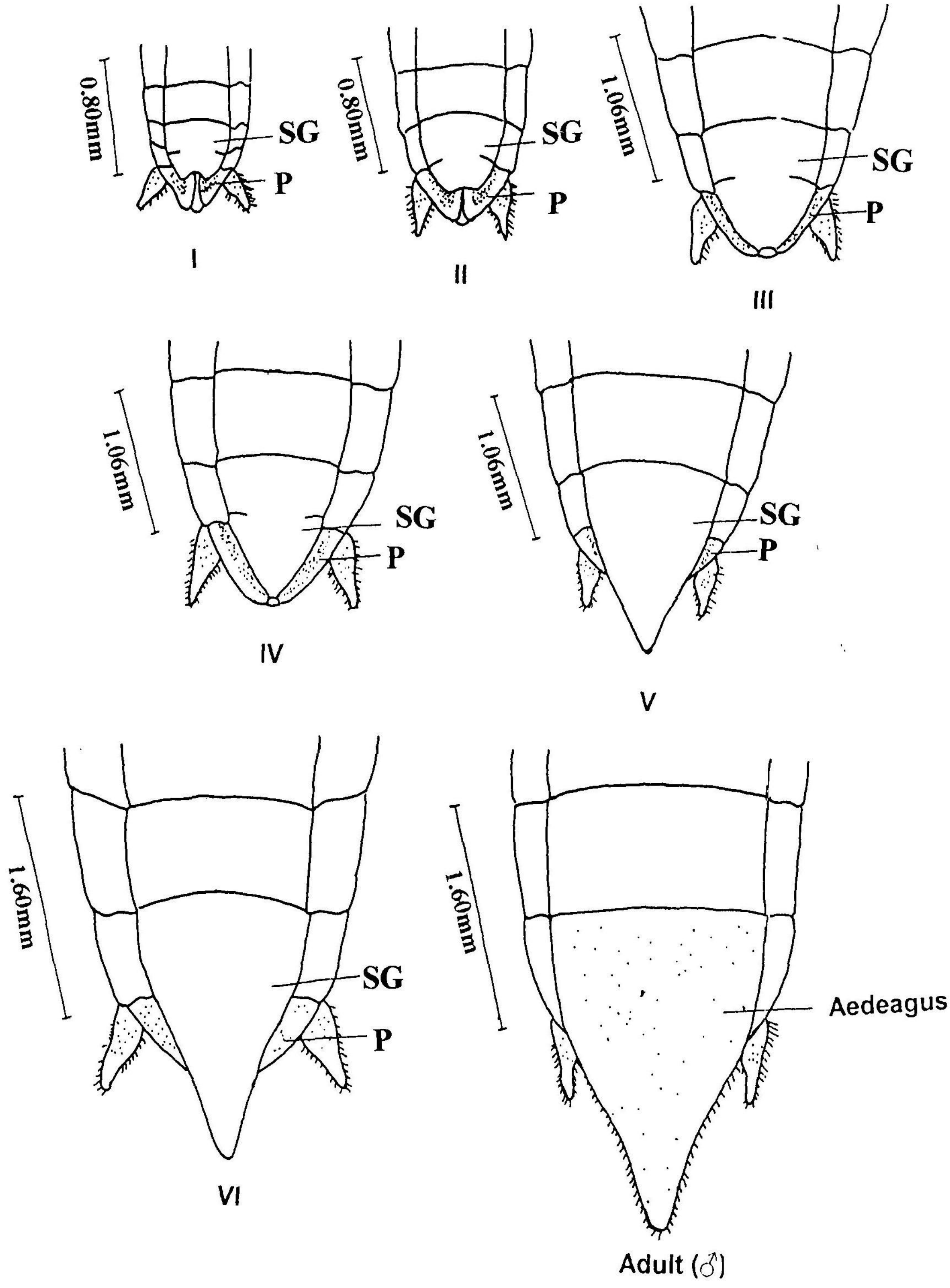


FIG.58. *Phlaeoba infumata* Brunn., growth of external genitalia of male

LV, LOWER OVIPOSITOR VALVE
UV, UPPER OVIPOSITOR VALVE
P, PARAPROCT

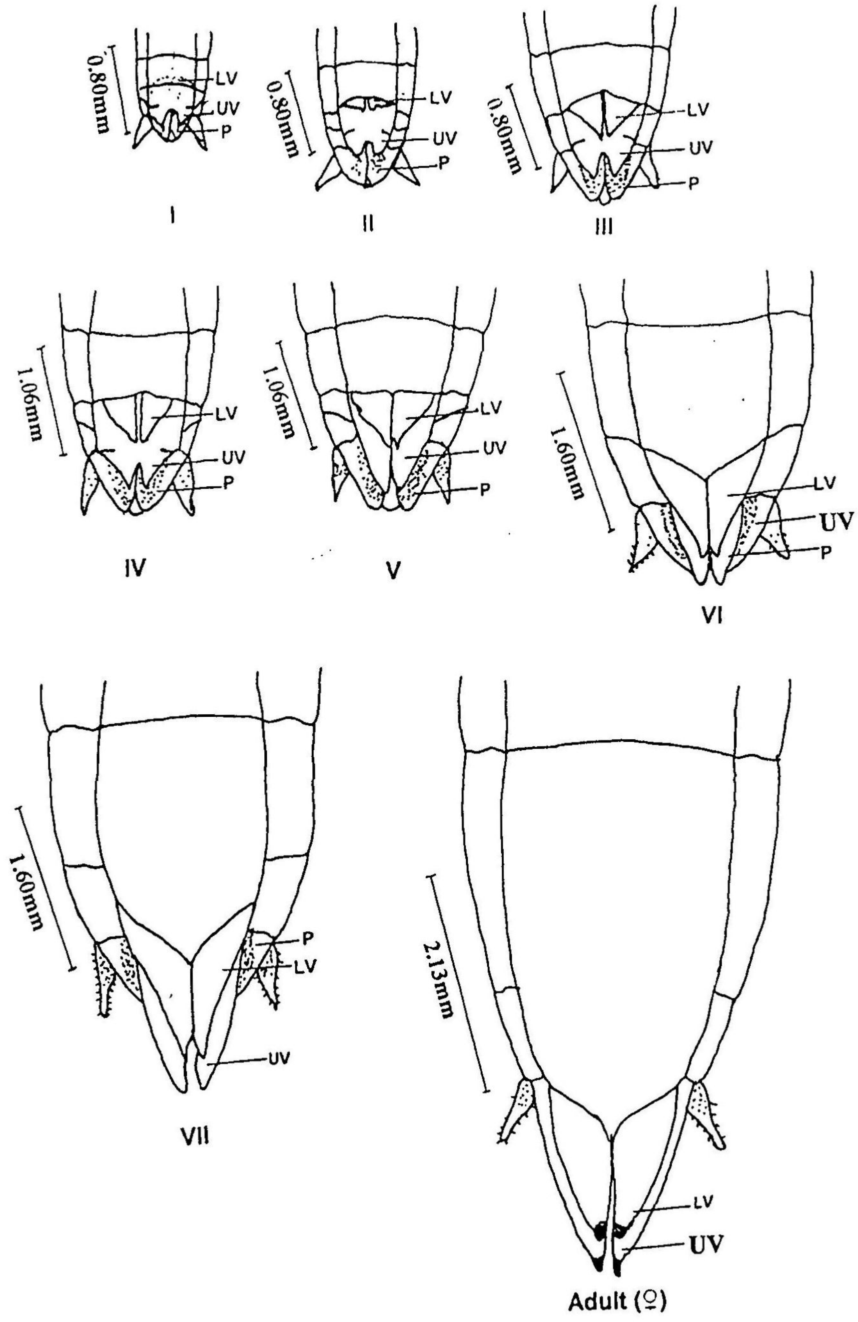


FIG.59. *Phlaeoba infumata* Brunn., growth of external genitalia of female

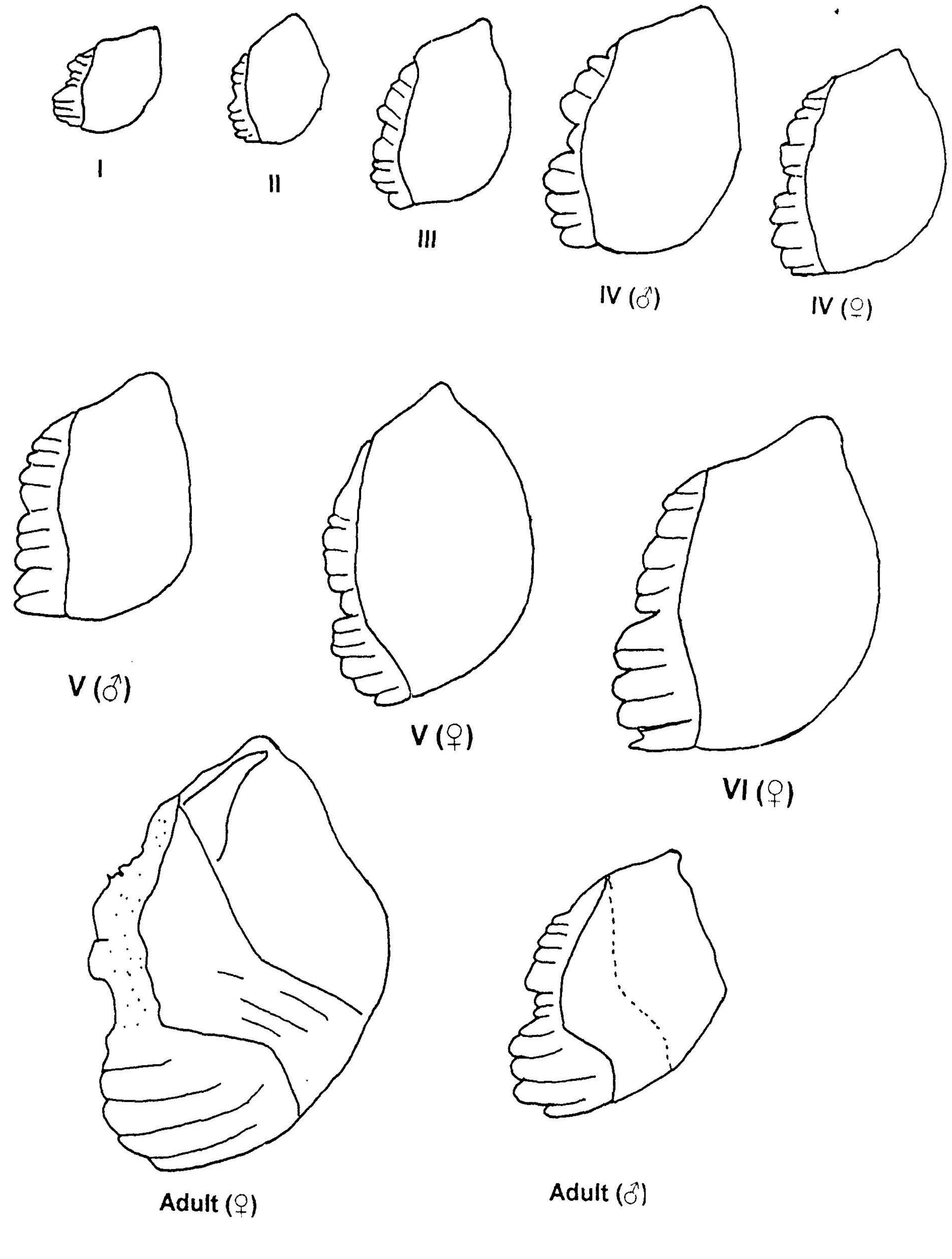


FIG.60. ***Phlaeoba infumata*** **Brunn., development of mandibular teeth**

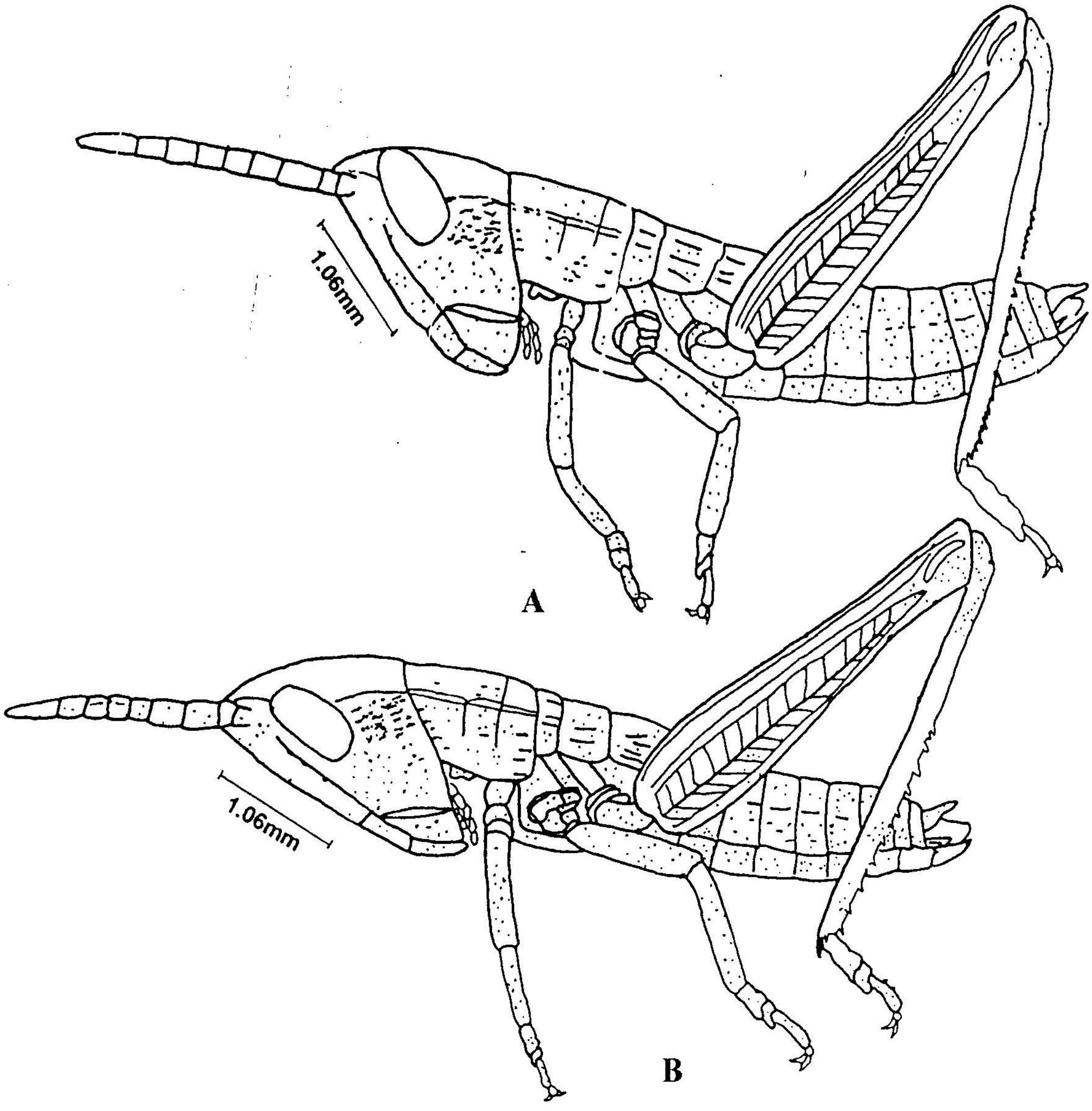


FIG.61. *Phlaeoba infumata* Brunn.

A – I INSTAR (FEMALE)

B – I INSTAR (MALE)

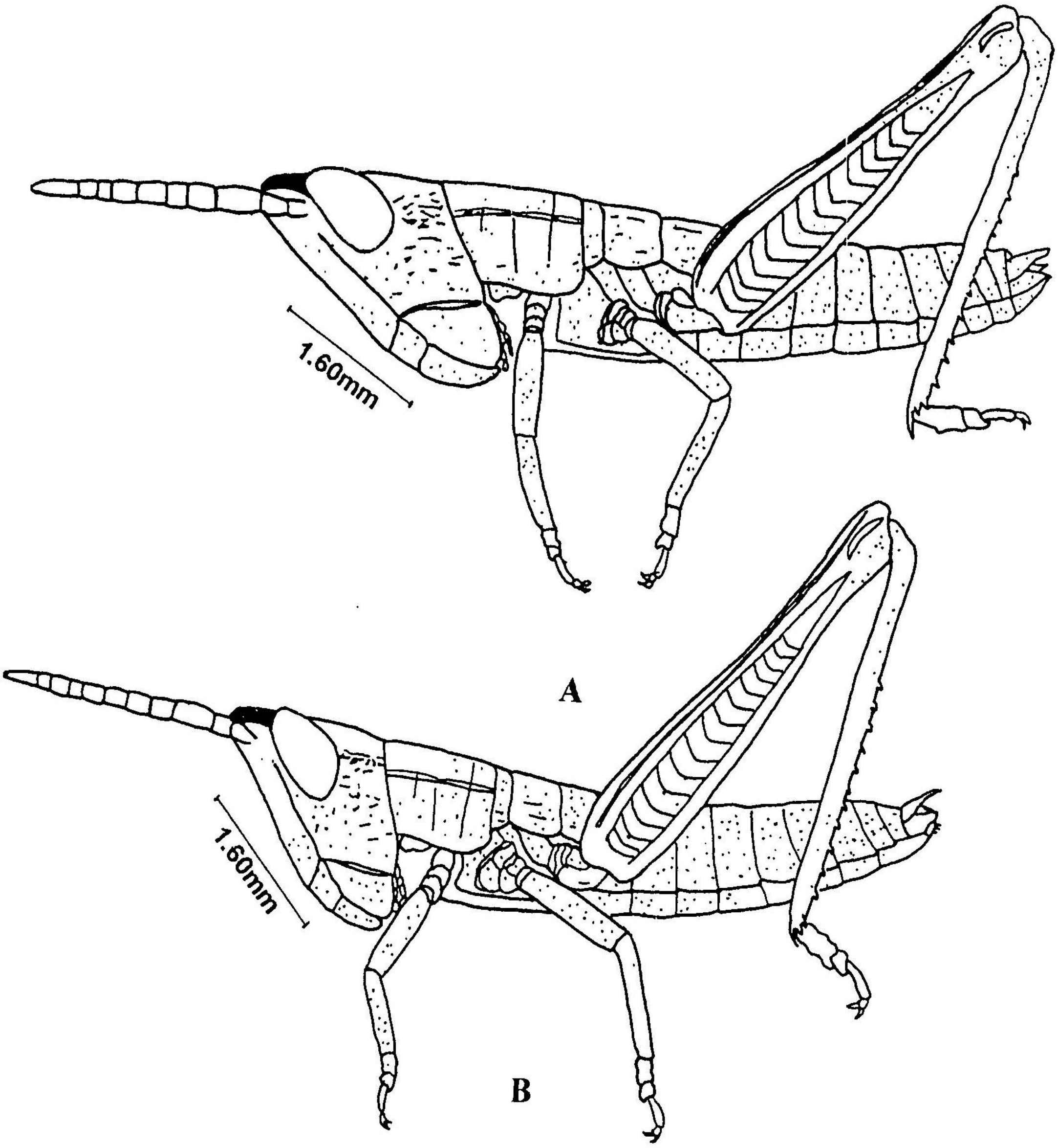


FIG.62. *Phlaeoba infumata* Brunn.

A – II INSTAR (FEMALE)

B – II INSTAR (MALE)

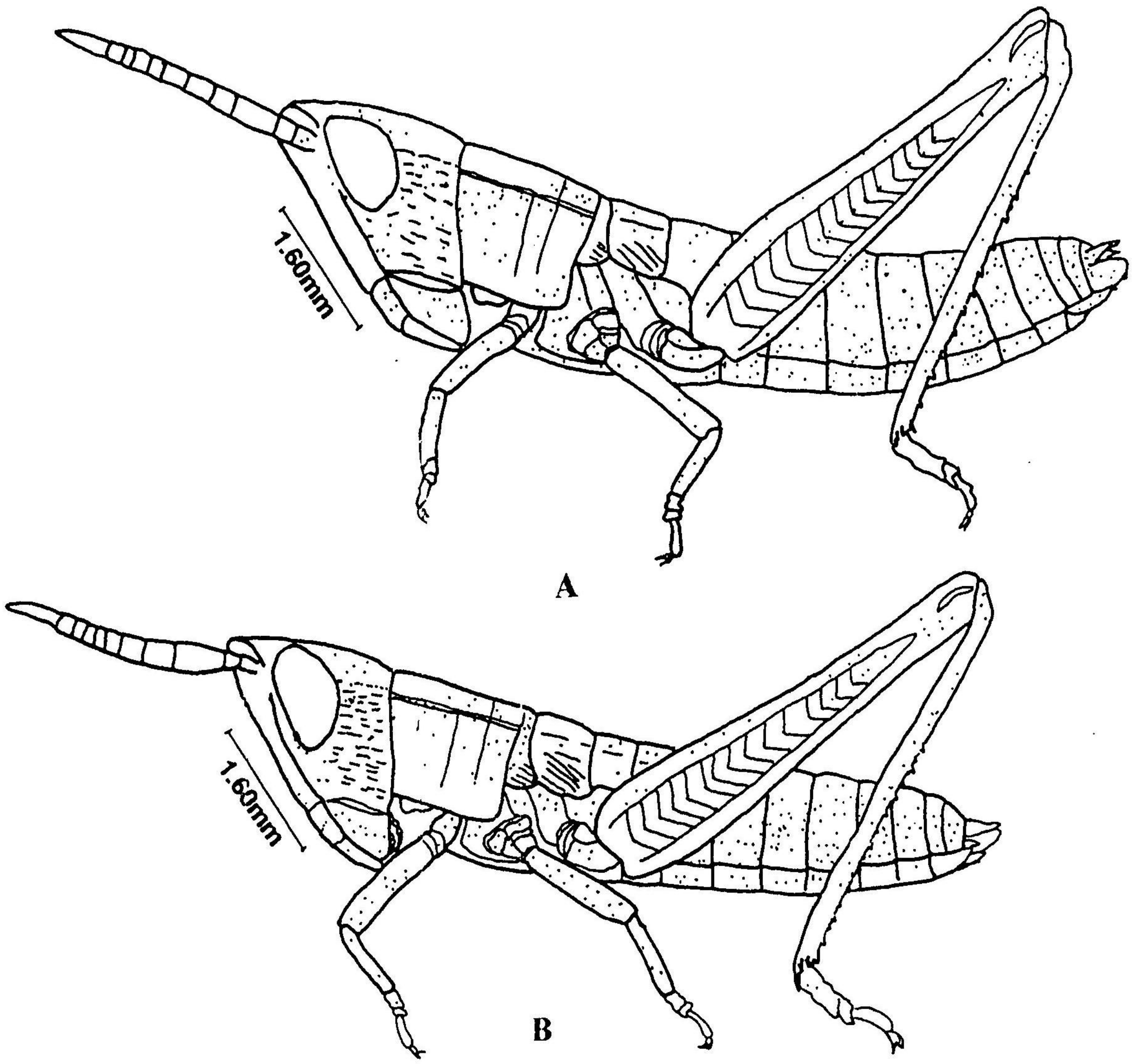


FIG.63. *Phlaeoba infumata* Brunn.

A – III INSTAR (FEMALE)

B – III INSTAR (MALE)

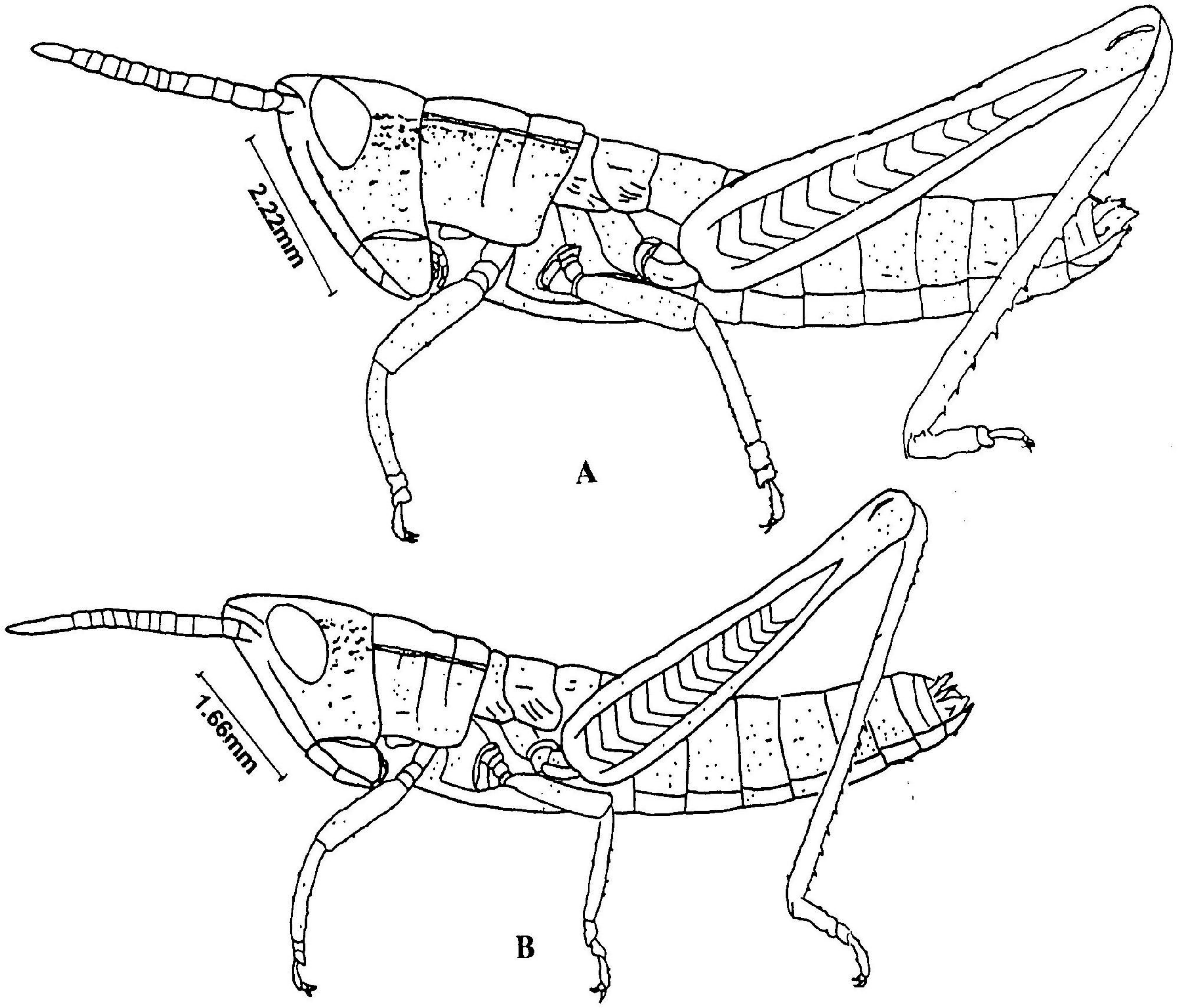


FIG.64. *Phlaeoba infumata* Brunn.

A – IV INSTAR (FEMALE)

B – IV INSTAR (MALE)

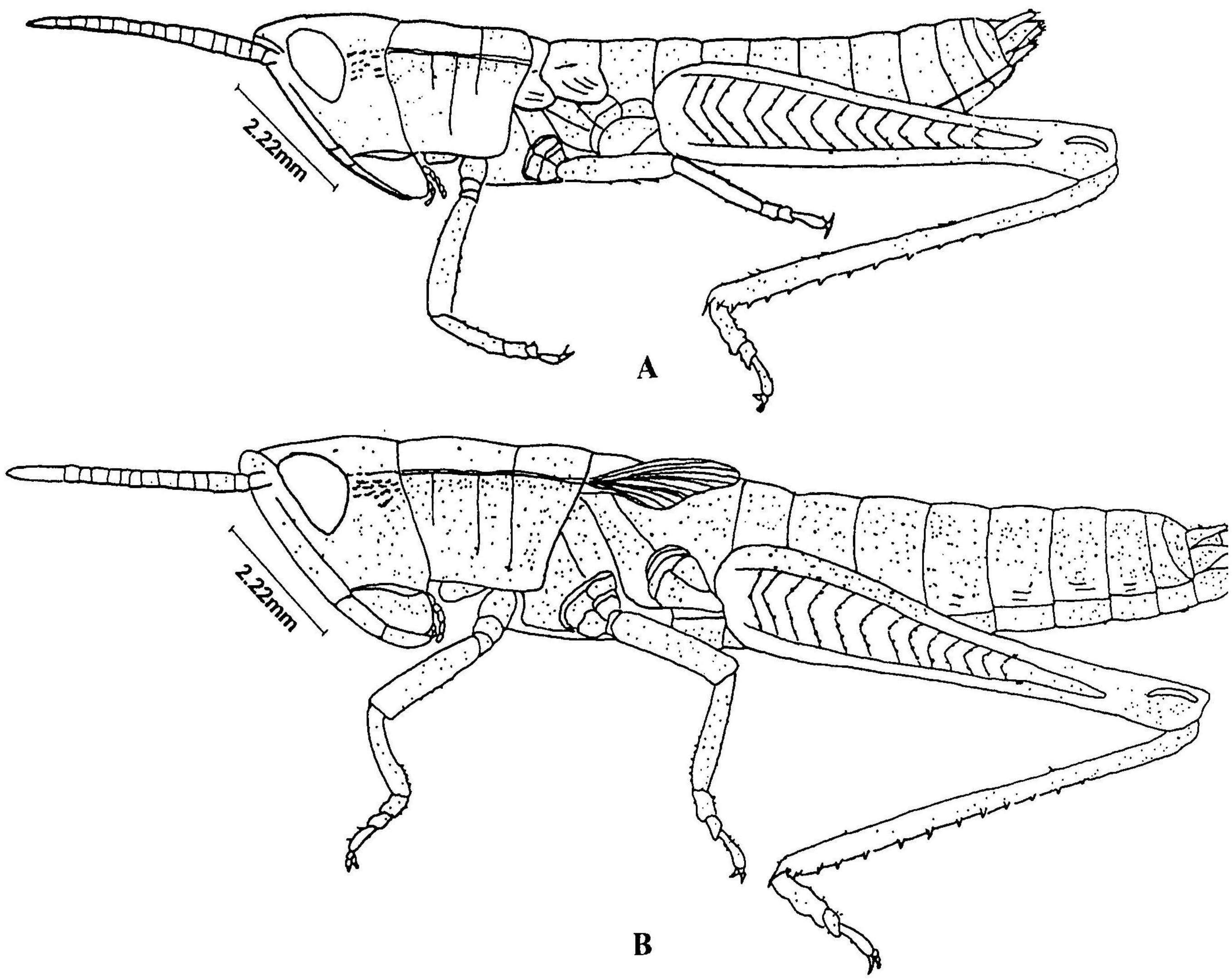


FIG.65. *Phlaeoba infumata* Brunn.

A – V INSTAR (FEMALE)

B – V INSTAR (MALE)

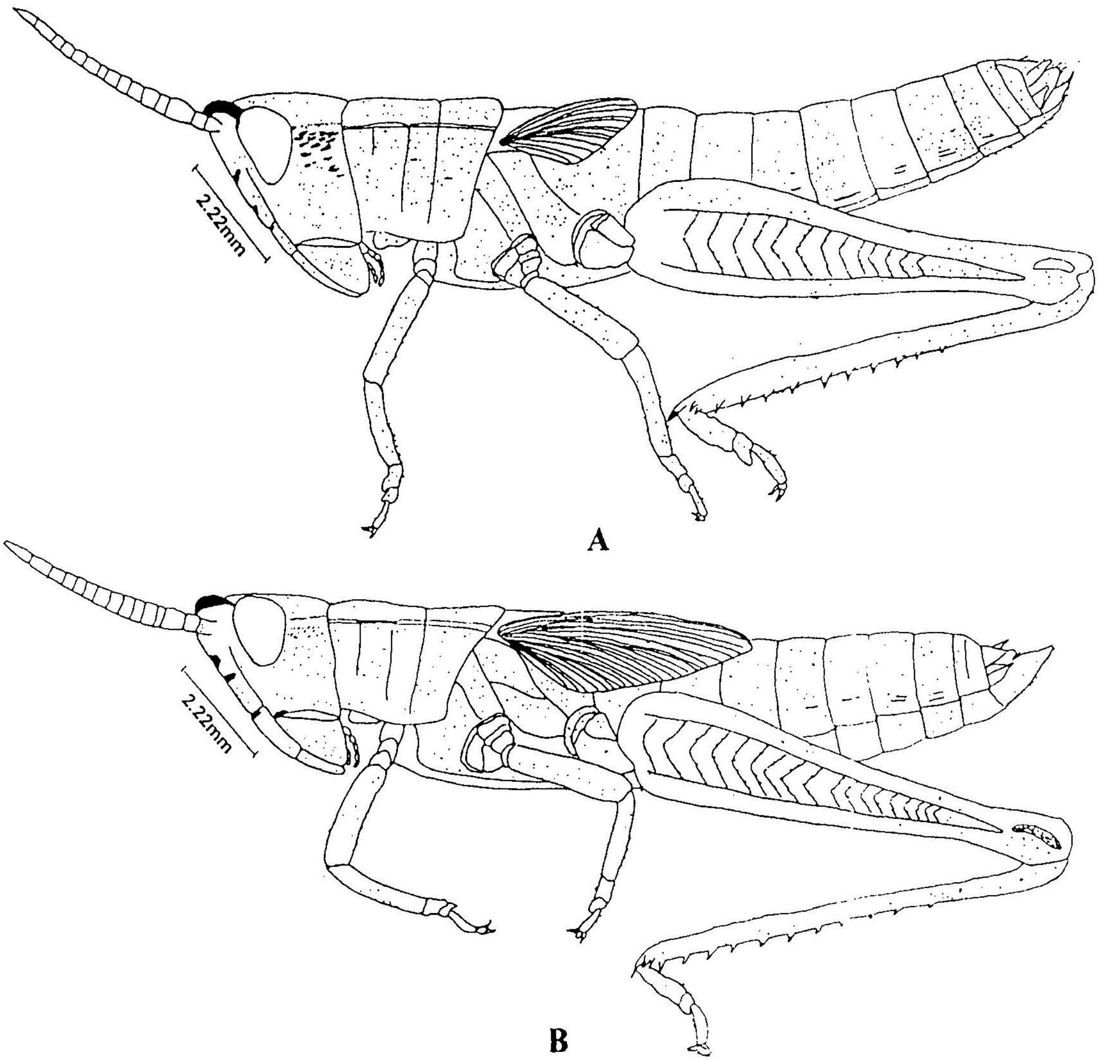


FIG.66. ***Phlaeoba infumata*** **Brunn.**

A – VI INSTAR (FEMALE)

B – VI INSTAR (MALE)

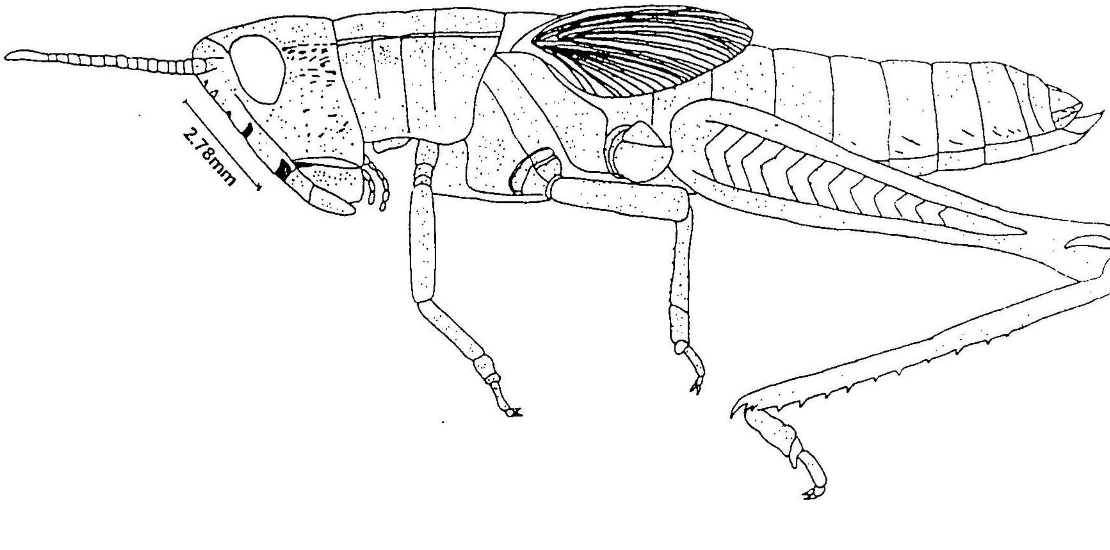


FIG.67. ***Phlaeoba infumata*** **Brunn.**

VII INSTAR (FEMALE)

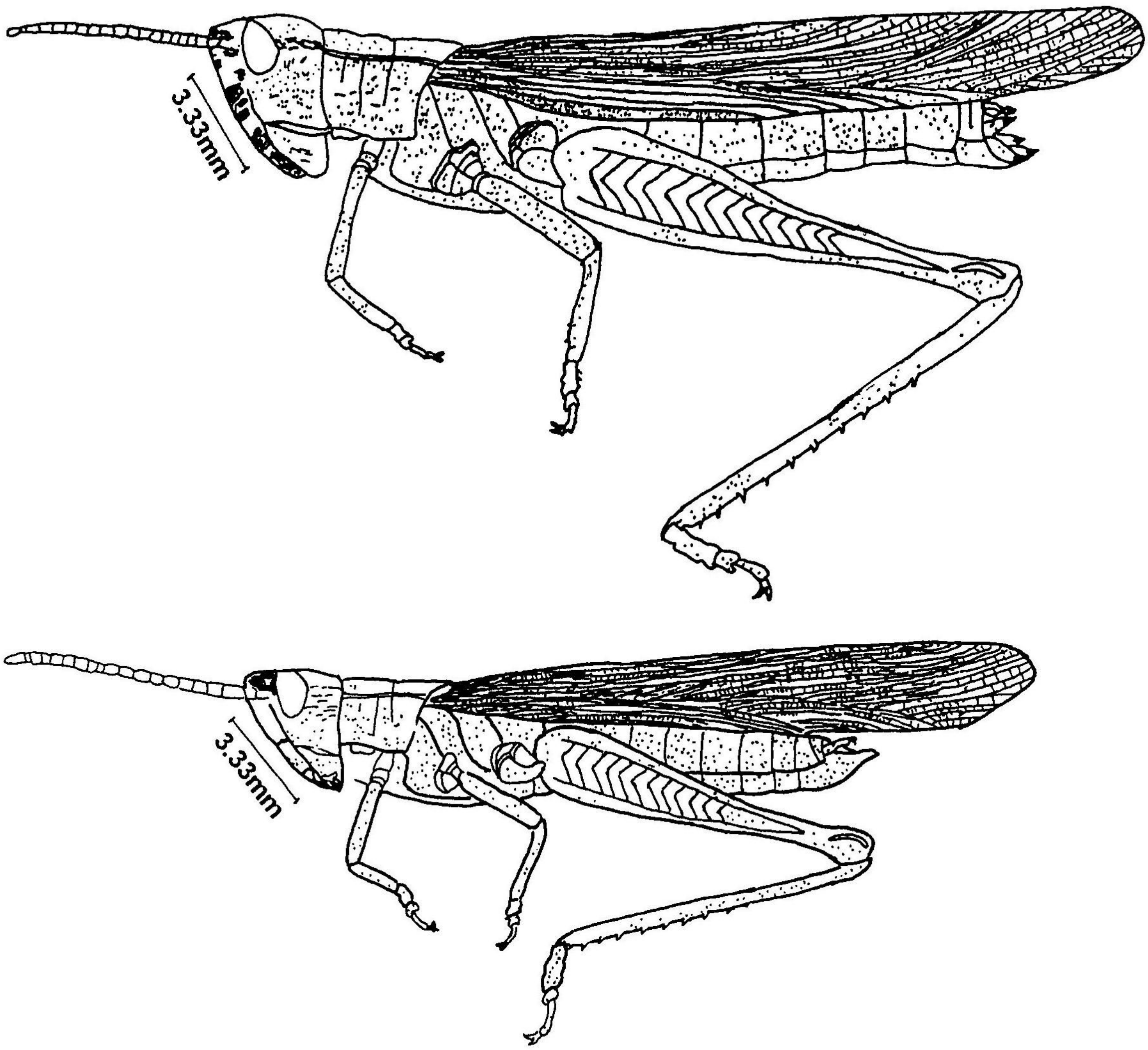
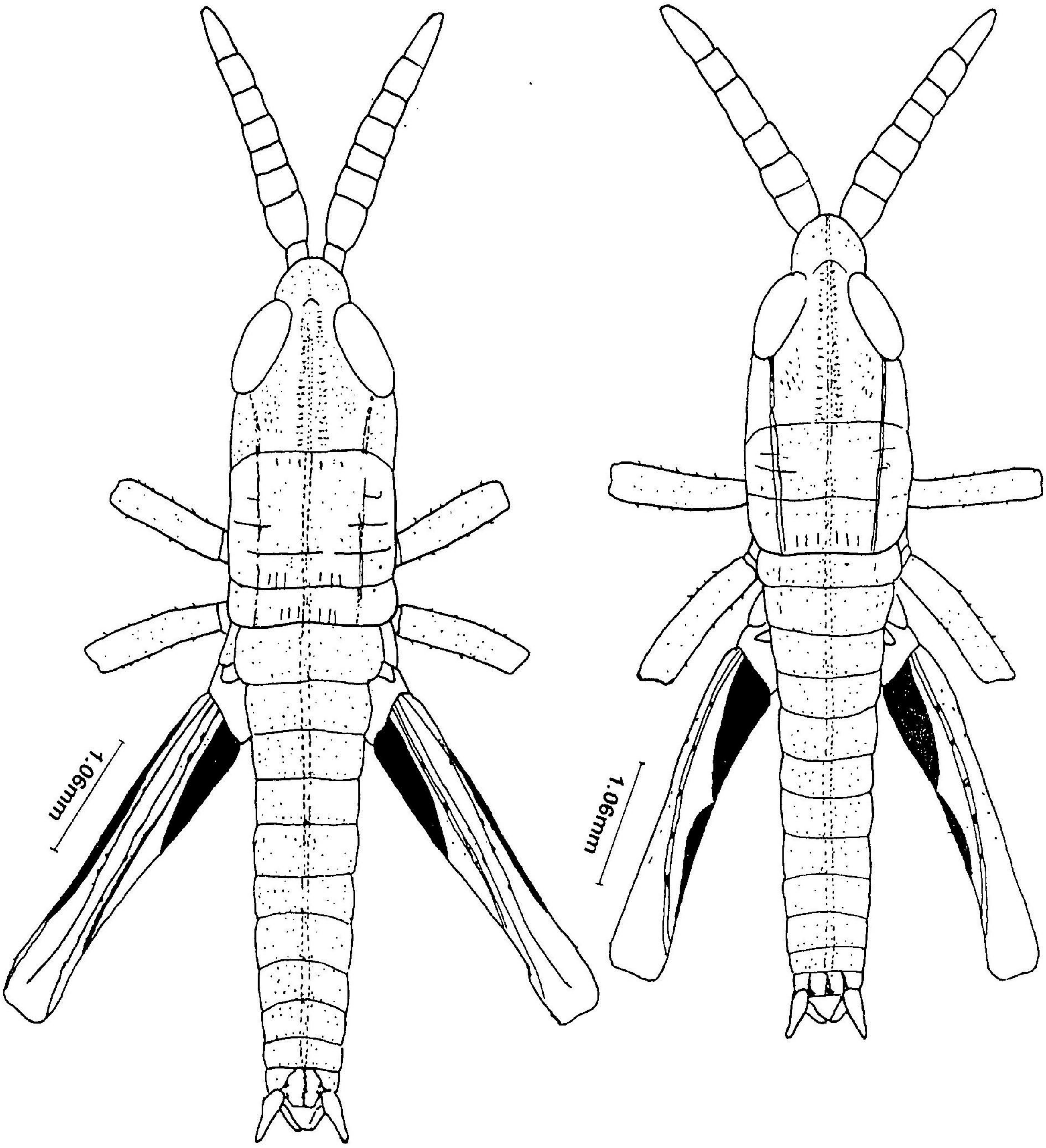


FIG.68. *Phlaeoba infumata* Brunn.

A – ADULT (FEMALE)

B – ADULT (MALE)



A B

FIG.69. *Phlaeoba infumata* Brunn.

A – I INSTAR (FEMALE)

B – I INSTAR (MALE)

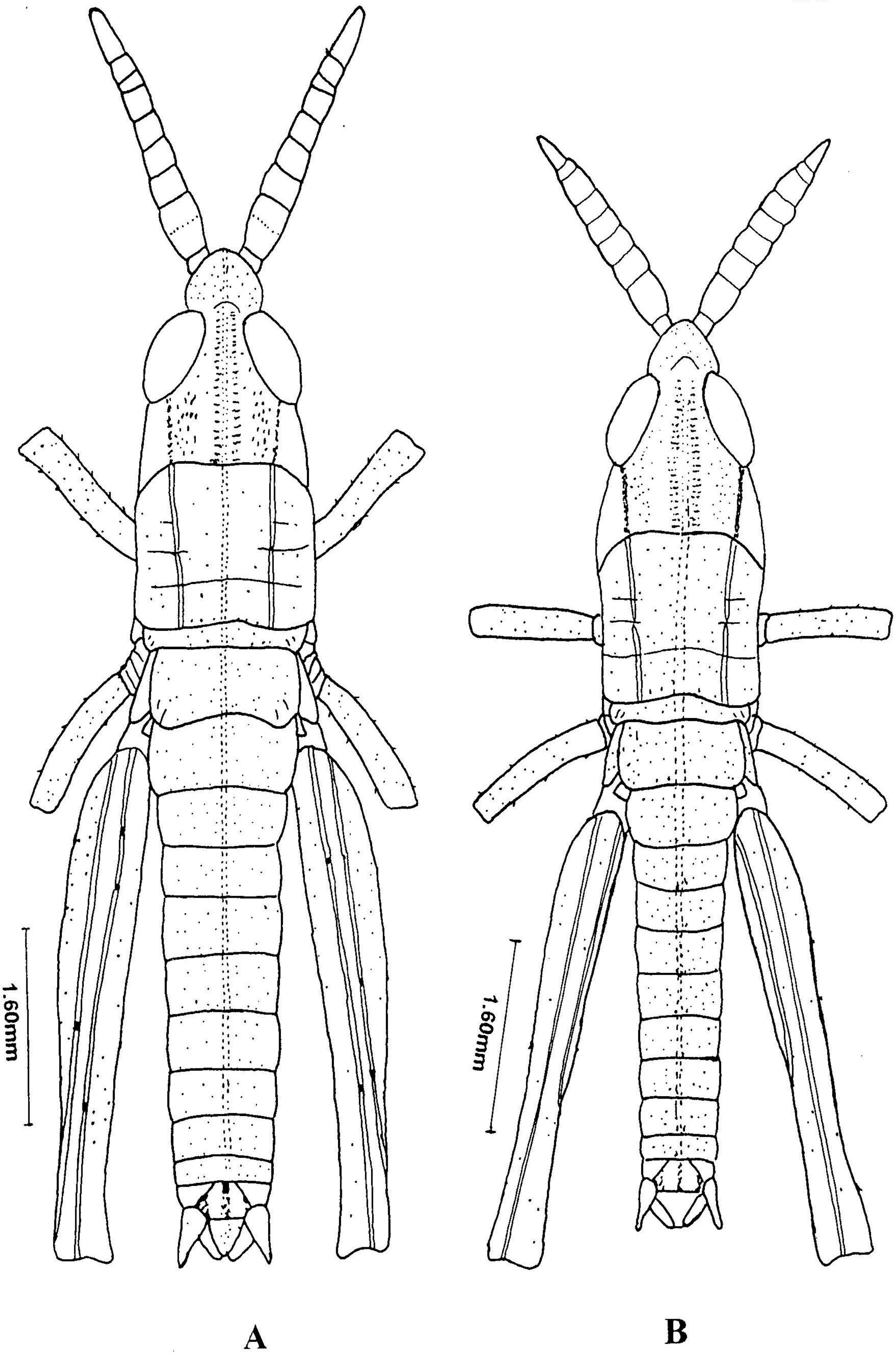


FIG.70. *Phlaeoba infumata* Brunn.

A – II INSTAR (FEMALE)

B – II INSTAR (MALE)

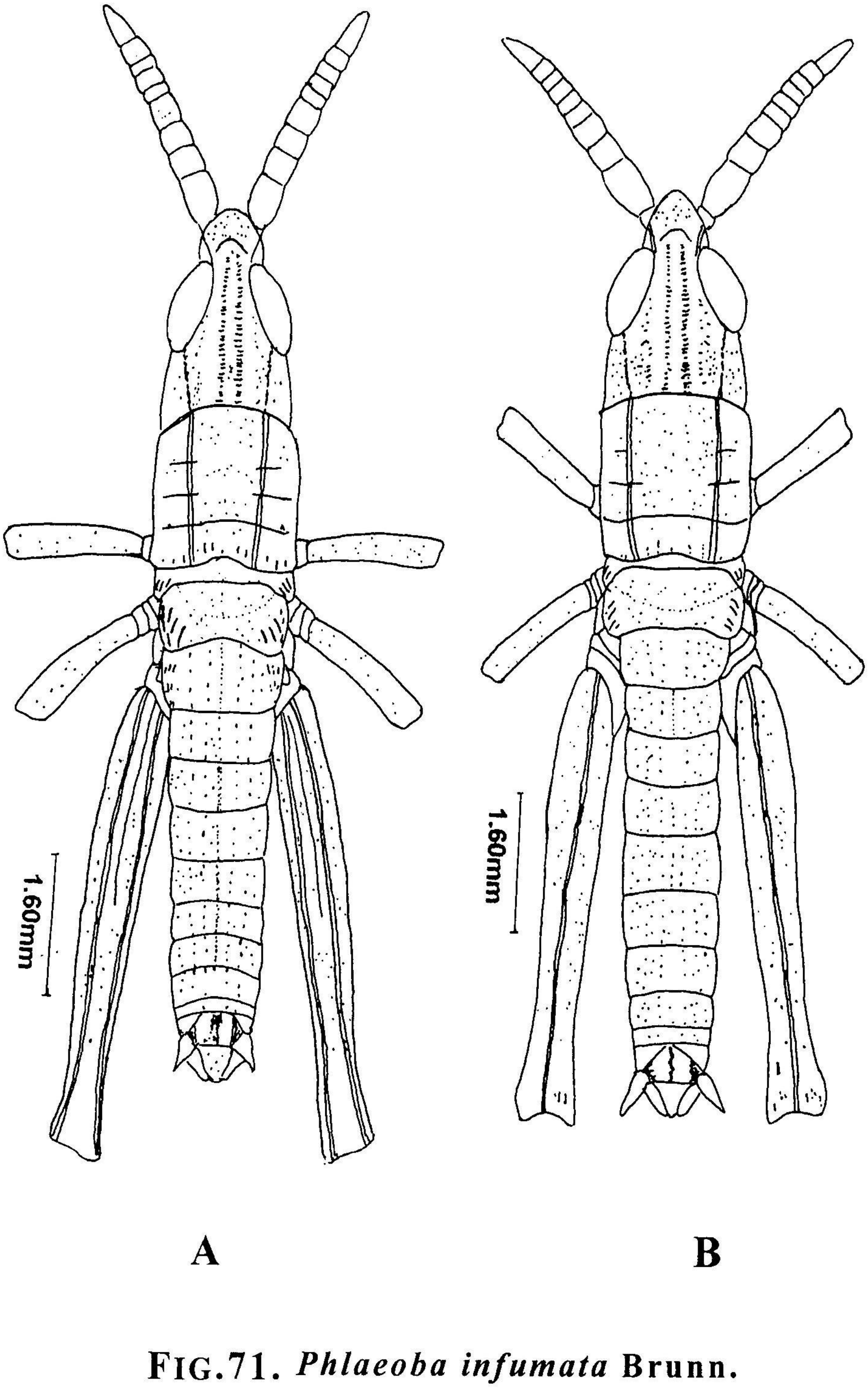


FIG.71. *Phlaeoba infumata* Brunn.

A – III INSTAR (FEMALE)

B – III INSTAR (MALE)

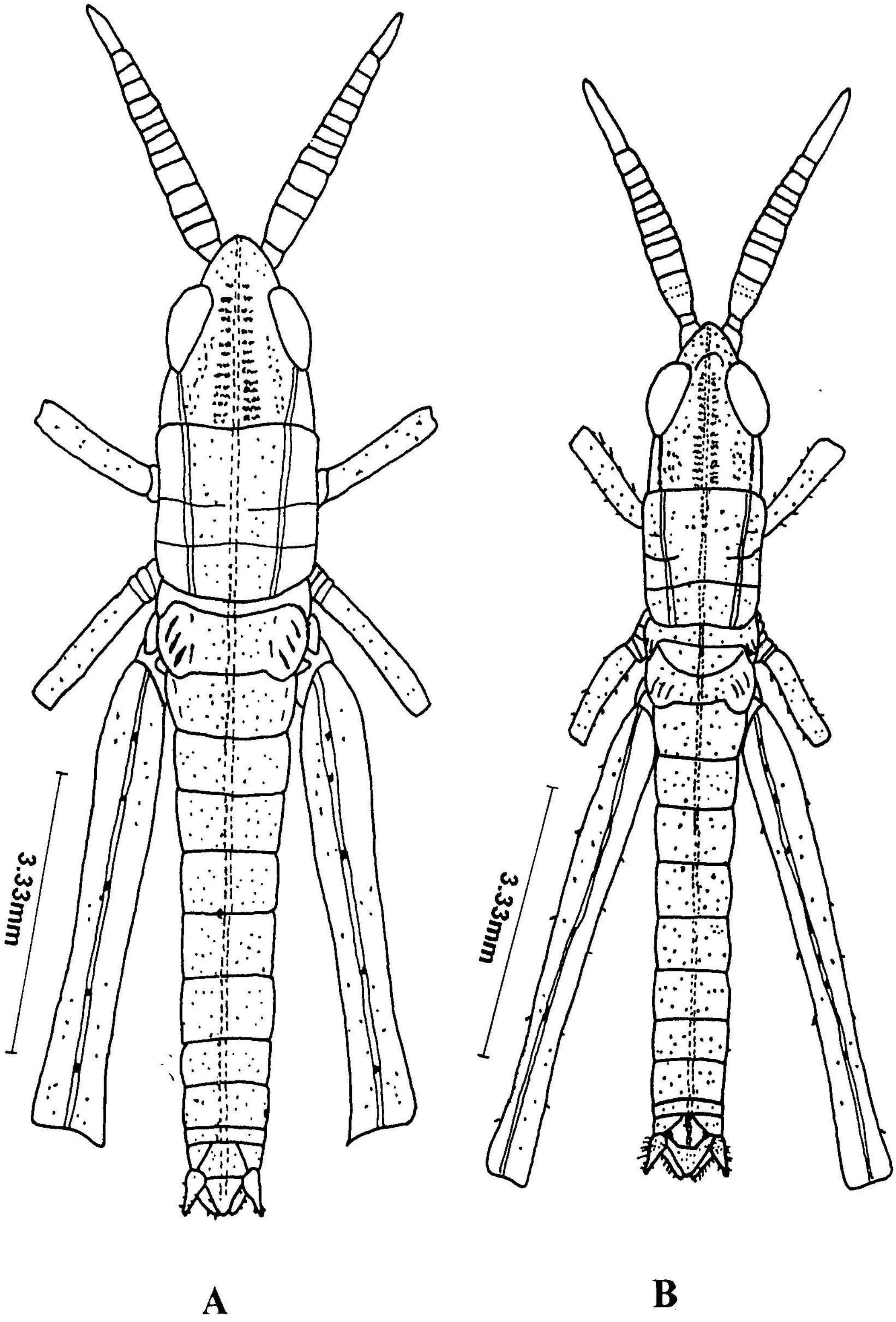
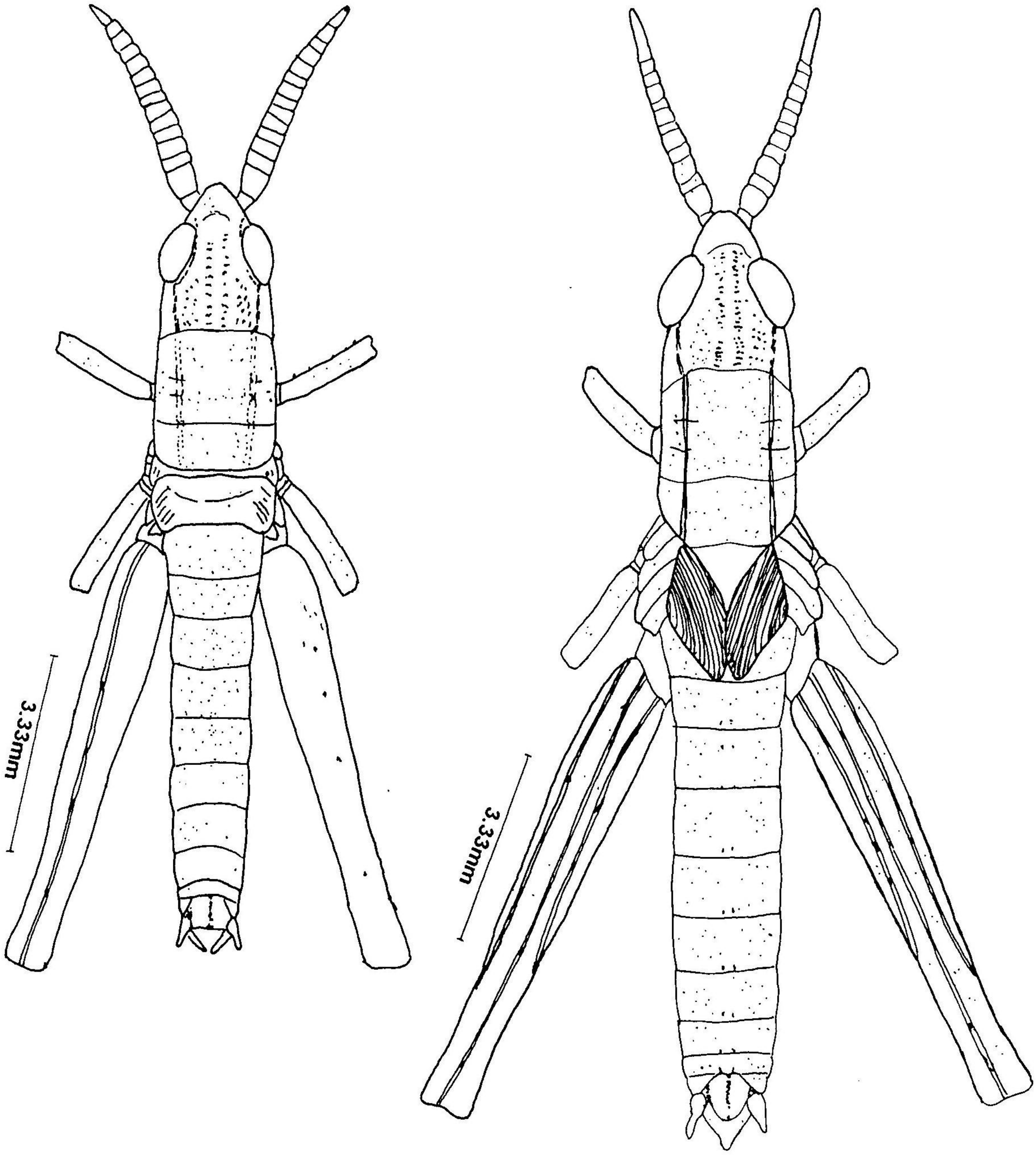


FIG.72. *Phlaeoba infumata* Brunn.

A – IV INSTAR (FEMALE)

B – IV INSTAR (MALE)



A B

FIG.73. *Phlaeoba infumata* Brunn.

A – V INSTAR (FEMALE)

B – V INSTAR (MALE)

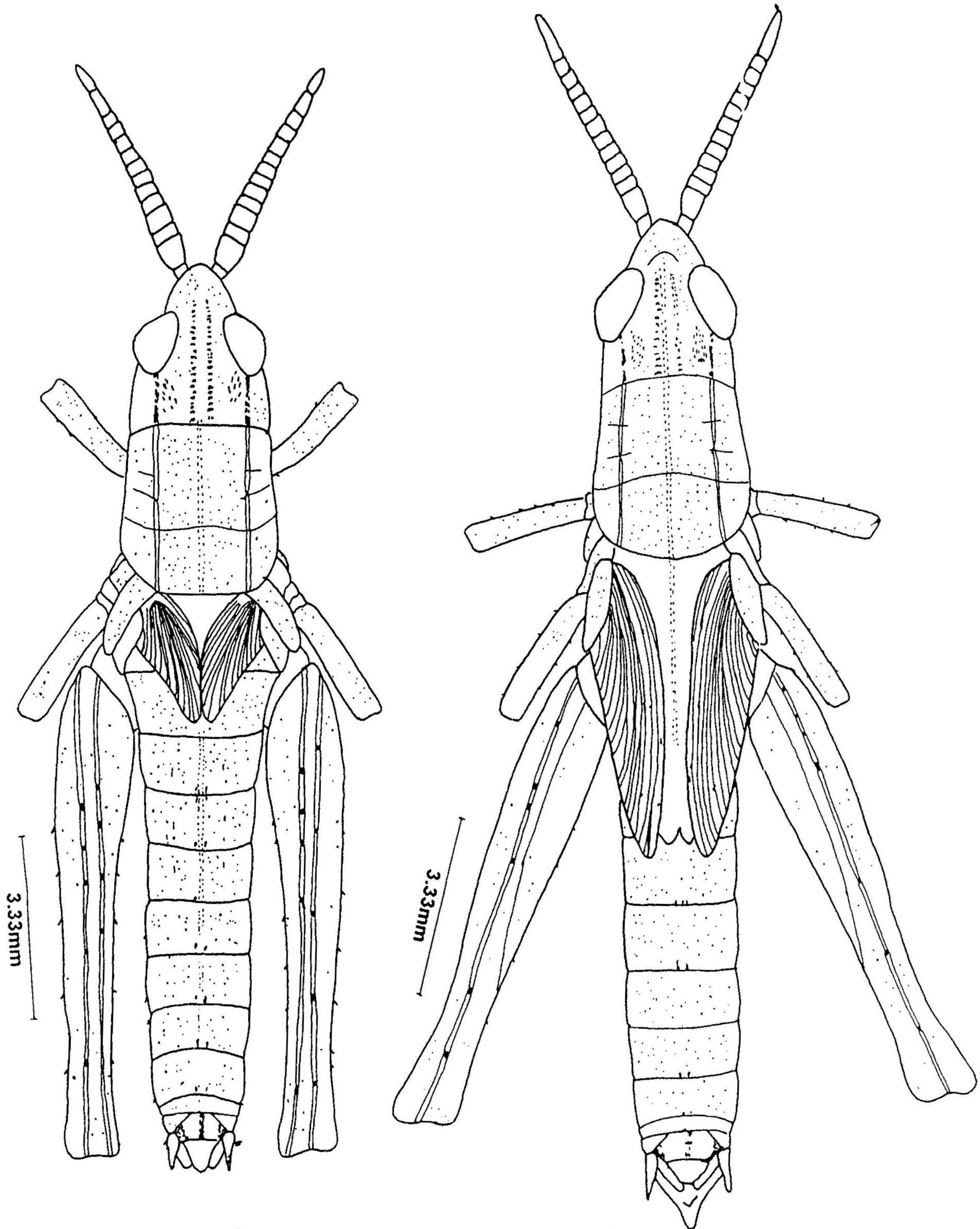


FIG.74. *Phlaeoba infumata* Brunn.

A – VI INSTAR (FEMALE)

B – VI INSTAR (MALE)

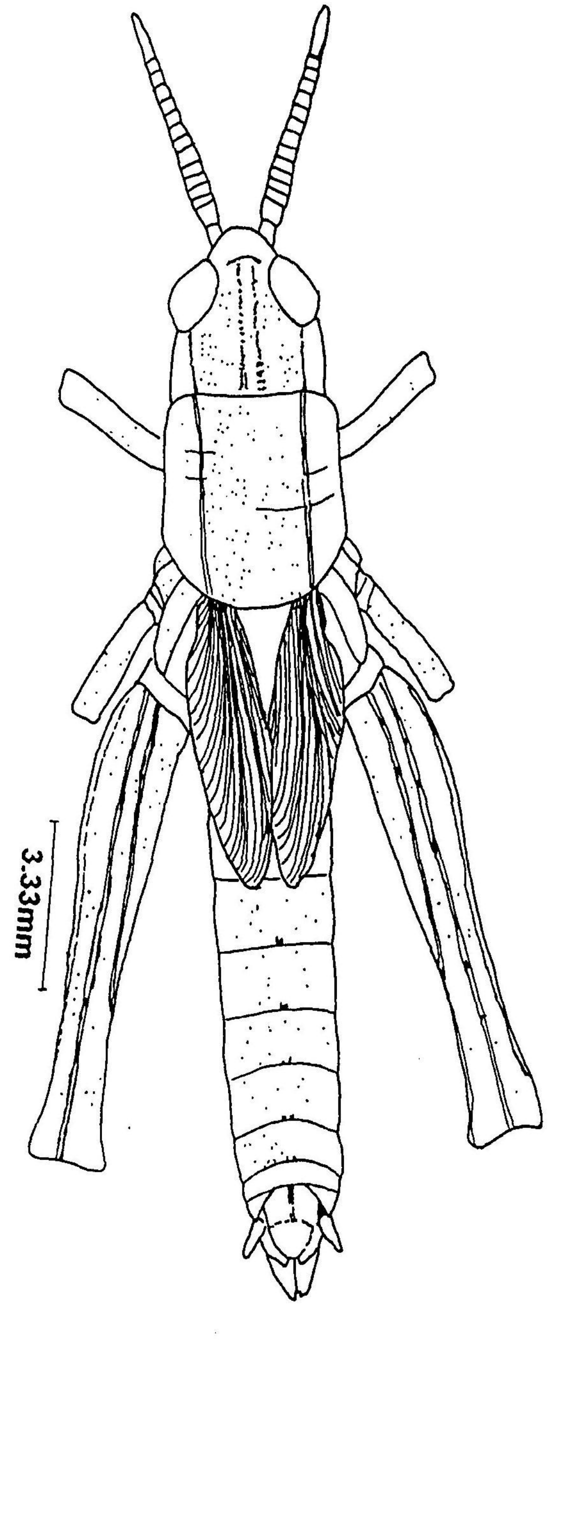


FIG.75. *Phlaeoba infumata* Brunn.
VII INSTAR (FEMALE)

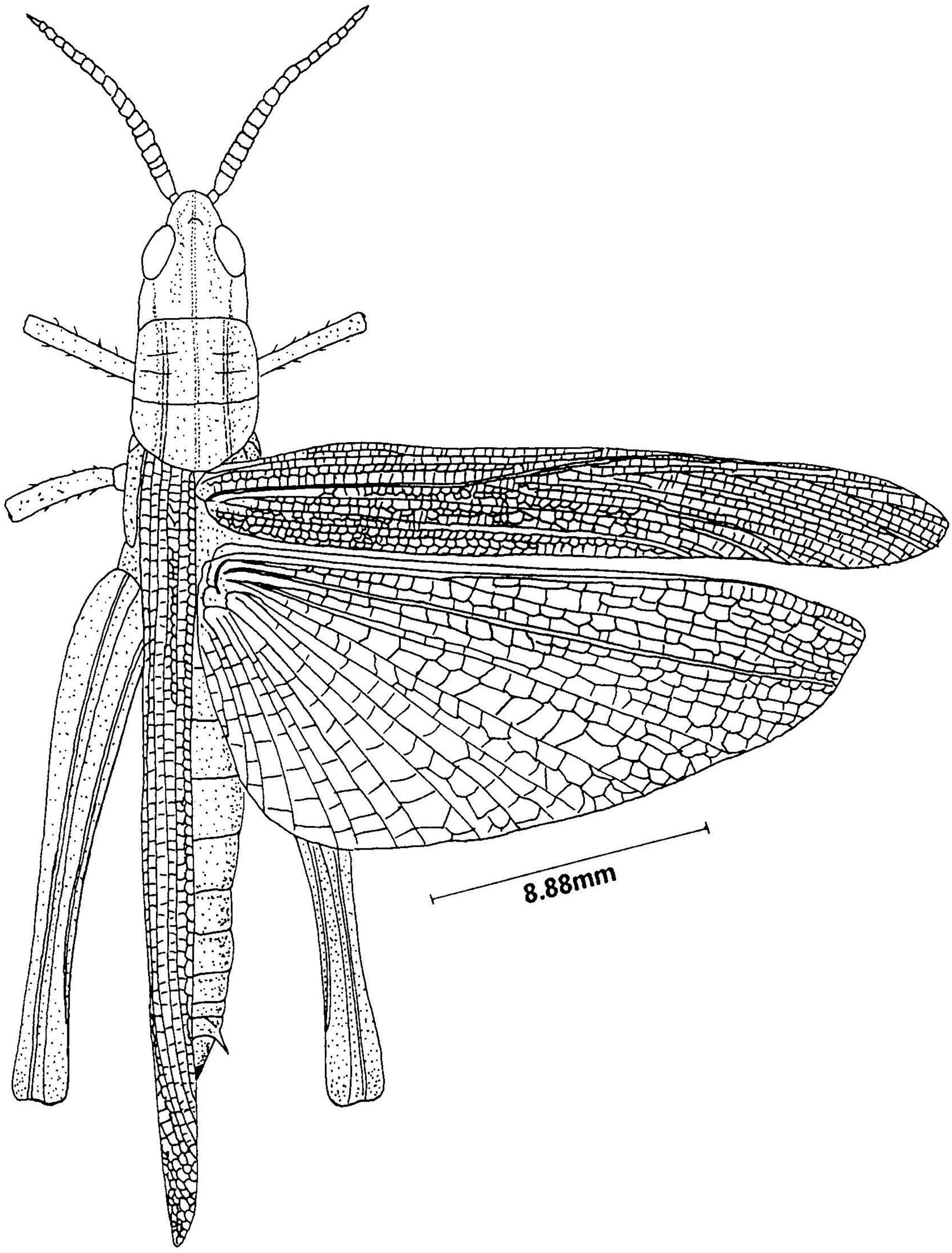


FIG.76. *Phlaeoba infumata* Brunn. (FEMALE)

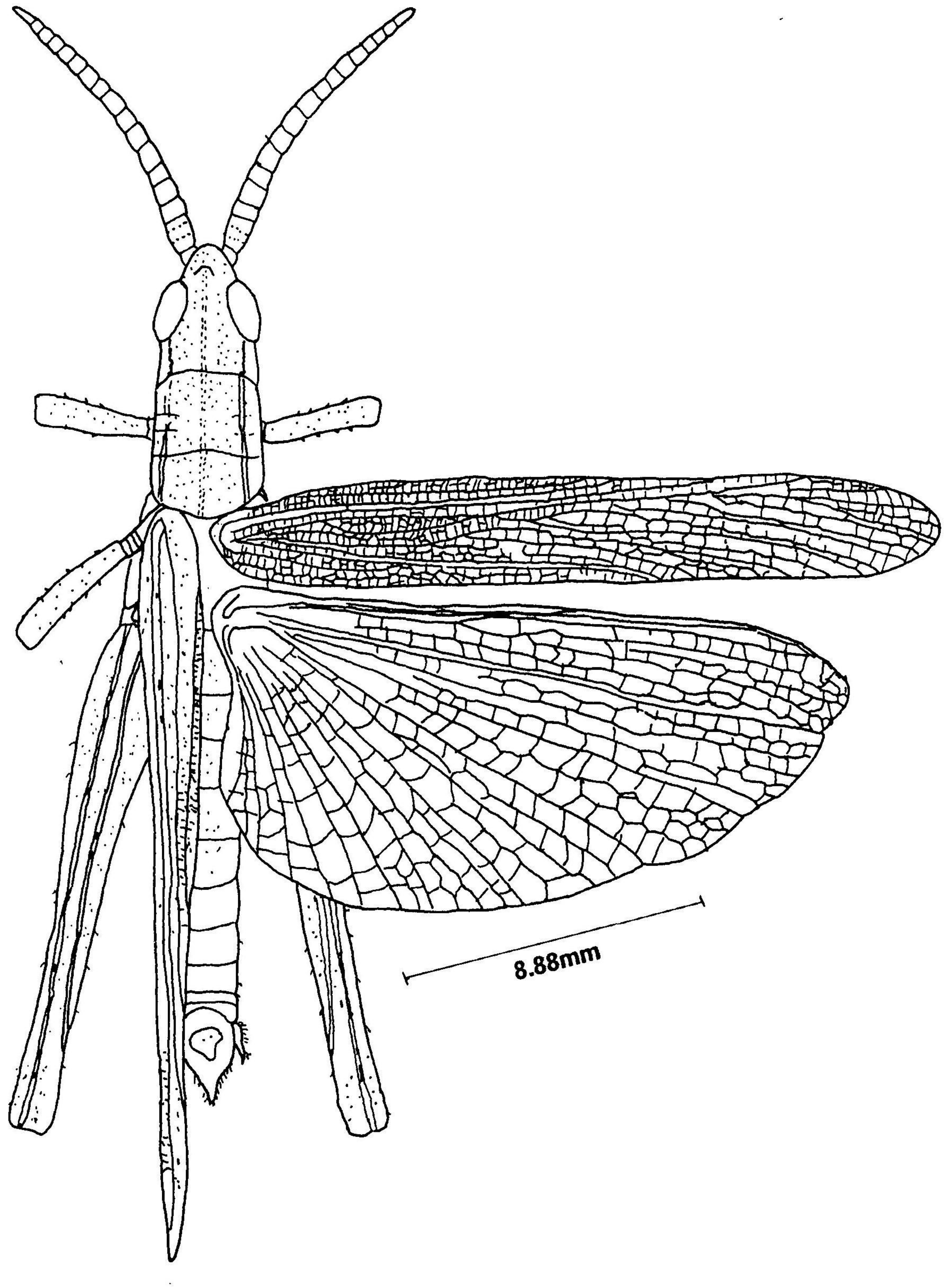


FIG.77. *Phlaeoba infumata* Brunn. (MALE)

About thirteen body parts of all stages of hoppers, including adults of both sexes, were measured. A comparative account of the rate of increase and the developmental mean rate are tabulated in Tables 27, 28 which is self explanatory. In the development of hoppers the key for the identification of instars and adults is prepared on the basis of the number of antennal segments which appear to be very significant.

The mandibles of the hoppers are typically of herbivorous type as these are overlapping and interlocking, incisor dents are pointed; left dents not longer than right; molar lobe with several subconical dents (Fig. 60).

Application of Dyar's law:

The Dyar's law (1890) was applied in this species because the successive formation of instars is a progressive development. The measurements of head width of the successive instars were taken separately in both sexes and within the same sex.

The head width in successive instars increases in a geometrical progression (Fig. 78). The average increase in each instar is 1.148 and 1.117, respectively for the male hopper instars

Table: 31. Application of Dyar's Law on the hoppers of *Phlaeoba infumata* Brunn.

(10 replicates)

Sex	Hopper instar	Observed width of head of hoppers (mm)	Calculated width of head of hoppers (mm)
Males with 5 instars	I instar	1.25	–
	II instar	1.38	1.14 × 1.148 = 1.435
	III instar	1.54	1.38 × 1.148 = 1.584
	IV instar	1.72	1.54 × 1.148 = 1.767
	V instar	2.16	1.72 × 1.148 = 1.974
Males with 6 instars	I instar	1.25	–
	II instar	1.38	1.25 × 1.117 = 1.396
	III instar	1.54	1.38 × 1.117 = 1.541
	IV instar	1.60	1.54 × 1.117 = 1.720
	V instar	2.93	1.60 × 1.117 = 1.854
	VI instar	2.19	1.93 × 1.117 = 2.155
Females with 6 instars	I instar	1.25	–
	II instar	1.40	1.25 × 1.148 = 1.435
	III instar	1.61	1.40 × 1.148 = 1.607
	IV instar	1.91	1.61 × 1.148 = 2.848
	V instar	2.30	1.91 × 1.148 = 2.192
	VI instar	3.87	2.30 × 1.148 = 2.640
Females with 7 instars	I instar	1.25	–
	II instar	1.40	1.25 × 1.117 = 1.396
	III instar	1.61	1.40 × 1.117 = 1.563
	IV instar	1.91	1.61 × 1.117 = 1.798
	V instar	2.25	1.91 × 1.117 = 2.130
	VI instar	2.67	2.25 × 1.117 = 2.513
	VII instar	3.04	2.67 × 1.117 = 2.982

Calculated width of head = Observed width of head × average ratio of increase in width of head

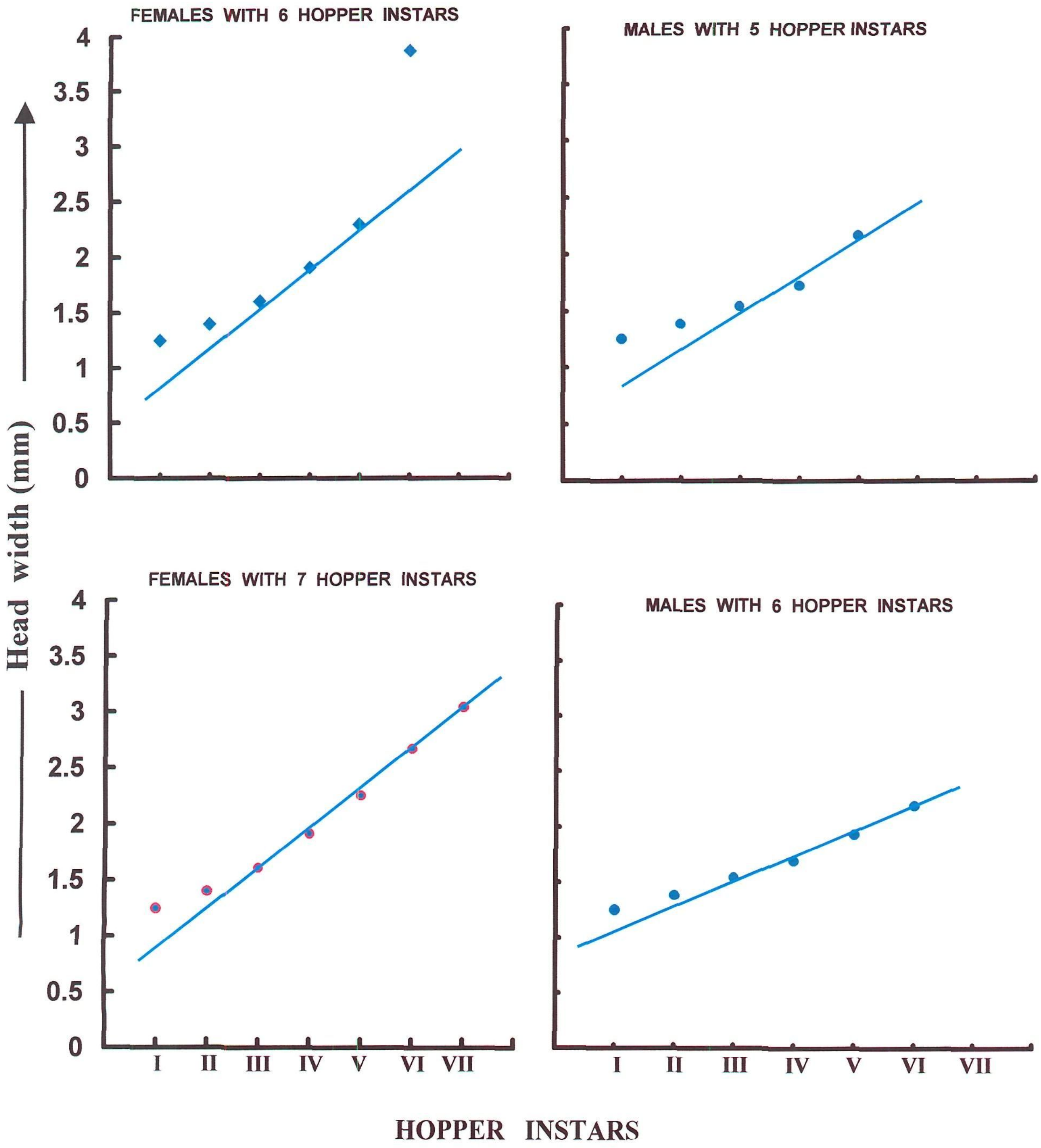


Fig: 78. Application of Dyar's law to *Phlaeoba infumata* Brunn.

having 5– and 6– hopper instars to become an adult stage and it remains the same as 1.148 and 1.117, respectively for the female hopper instars having 6– and 8– hopper instars before they reach the adult stage. The calculated head width is found close to the observed head width (Table 31). These figures are enough to determine the instars and eliminate any possibility of missing any ecdysis in the life–cycle. Although the above figures are not completely identical and are sufficient to infer that the increase in head width follows Dyar's law.

(ii) LIFE CYLCE IN THE FIELD:

There are generally two complete generations in a year and the third one was found overlapping and rather incomplete. The first hatching was recorded in the last week of May, 2001 and such hatchings continued up to August. Development of various stages completed up to the last week of October. During development they increase their size and become final instar hopper to finally moult into an adult stage. In the first week of November, copulation was recorded and within a week egg–laying took place. Such eggs hibernate during December, January and up to the second week of February. This was on the same pattern as with other acridoids in temperate climates with cold winters as found in Aligarh. This might be considered as a winter diapause. In the last week of February there was an expected shower resulting in hatching of this species and such hatching was recorded up to the last week of March. This hatching of hoppers and completion of development was completed by the first week of May when they become sexually mature. In this way the second generation was started in February and completed in April.

The first generation passes through the April and May and the second generation passes through October and November. There was no obligatory diapause. The above description is based on complete recordings of two generations in the year 2001 – 2003. Overlapping generations and presence of various stages of *Phlaeoba infumata* throughout the year suggests that there are more than two generations depending upon the environmental factors such as temperature and humidity.

Some variations in the hatching period, and time of development of *Phlaeoba infumata* can be attributed to various temperature regimes experienced by egg-pods, availability of preferred food and conducive egg-laying sites.

The seasonal variations in the field population of *Phlaeoba infumata* in different months of the year, 2001–2003 on the basis of fortnightly capture with daily recording of temperature, relative humidity alongwith rainfall are given in Figs. 5, 6, 7 & 79, 80.

The adults of this species were found quite active in December and January as well but their reproductive activity was at the lowest ebb. Likewise, the hopper stages, mostly late instar hoppers, were also found in extreme cold months showing unusual long duration in the nymphal instars. Obviously it can be attributed to an exceptional ability of an ecological adaptation to severe cold and to pass unfavourable condition. This is not commonly found in species regularly confined to temperate climate.

CHAPTER – IV

(B) POPULATION STUDIES

The population studies of *Phlaeoba infumata*, with reference to seasonal variations in a year are based on numerical values of all stages of sex populations. In addition to it, special importance was paid to their small scale movements.

(a)Seasonal variations:

Phlaeoba infumata is found, throughout North India and almost all stages could be seen during extreme climate. Normally they are abundant in short grasses like *Cynodon dactylon* Pers., and during rainy season they enter into tall grasses like *Panicum psilopodium* Trin. The local open savanna in Aligarh consists of the following grasses:

Cyperus rotundus Lin., *Paspalum distichum* Linn., *Seteria glauca* (L.) *Beauv.*, *Andropogon adoratus* Linn., *Panicum psilopodium* Trin., and *Cynodon dactylon* Pers., was found to be mostly preferred by *Phlaeoba infumata*. There were two complete generations in a year with third incomplete generation. In the month of September and October the population of adults and final instar hoppers has considerable size while it dwindles in the month of December and January. The seasonal variations in the population of *this species* on the basis of monthly records for three years, 2001, 2002, and 2003 are shown in Figs. 79, 80. The relative abundance in different months of the year in relation to temperature and humidity and rainfall has been shown in Figs. 79, 80 and meteorological data in Figs. 5, 6 and 7.

This species has never been found totally absent from breeding grounds. Occasional or abrupt depletion in population has been due to sudden changes in the environmental conditions.

(b)Variations in sex population:

The sex ratios in the nymphal instars for the years, 2001, 2002 and 2003, were recorded as 1:1 in first instar hoppers. The ratio oscillates in subsequent nymphal instars but finally the ratios in the adults are in favour of females than males. This is due to high mortality among males. In some areas the male population was exceeding the female. This male excess ratio was recorded in September, which dwindles in October onwards, while the female population increased and stabilized in the month of October and November. This may be attributed to the post copulatory exhaustion

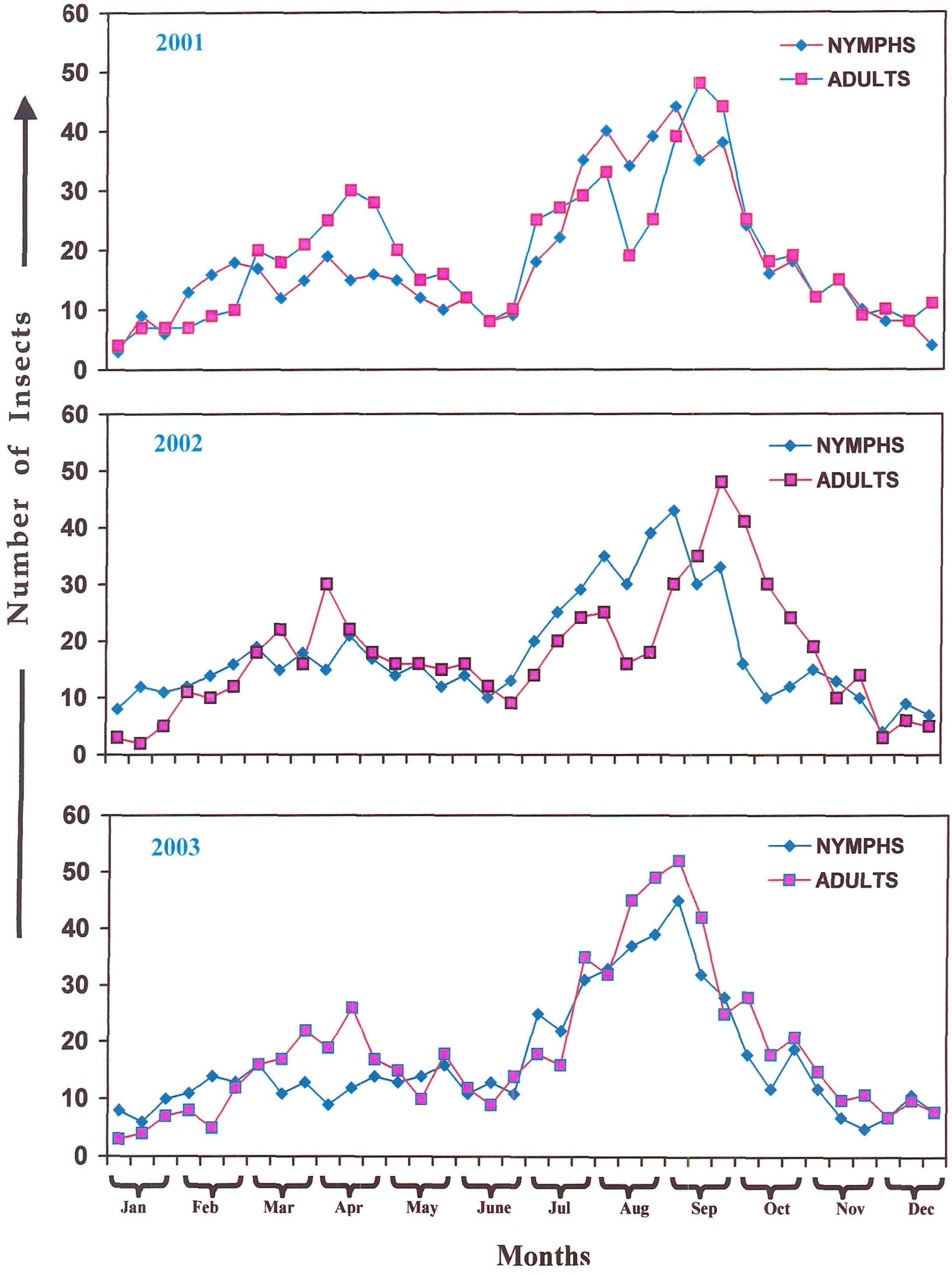


Fig.79. Natural population estimation of *Phlaeoba infumata* Brunn.

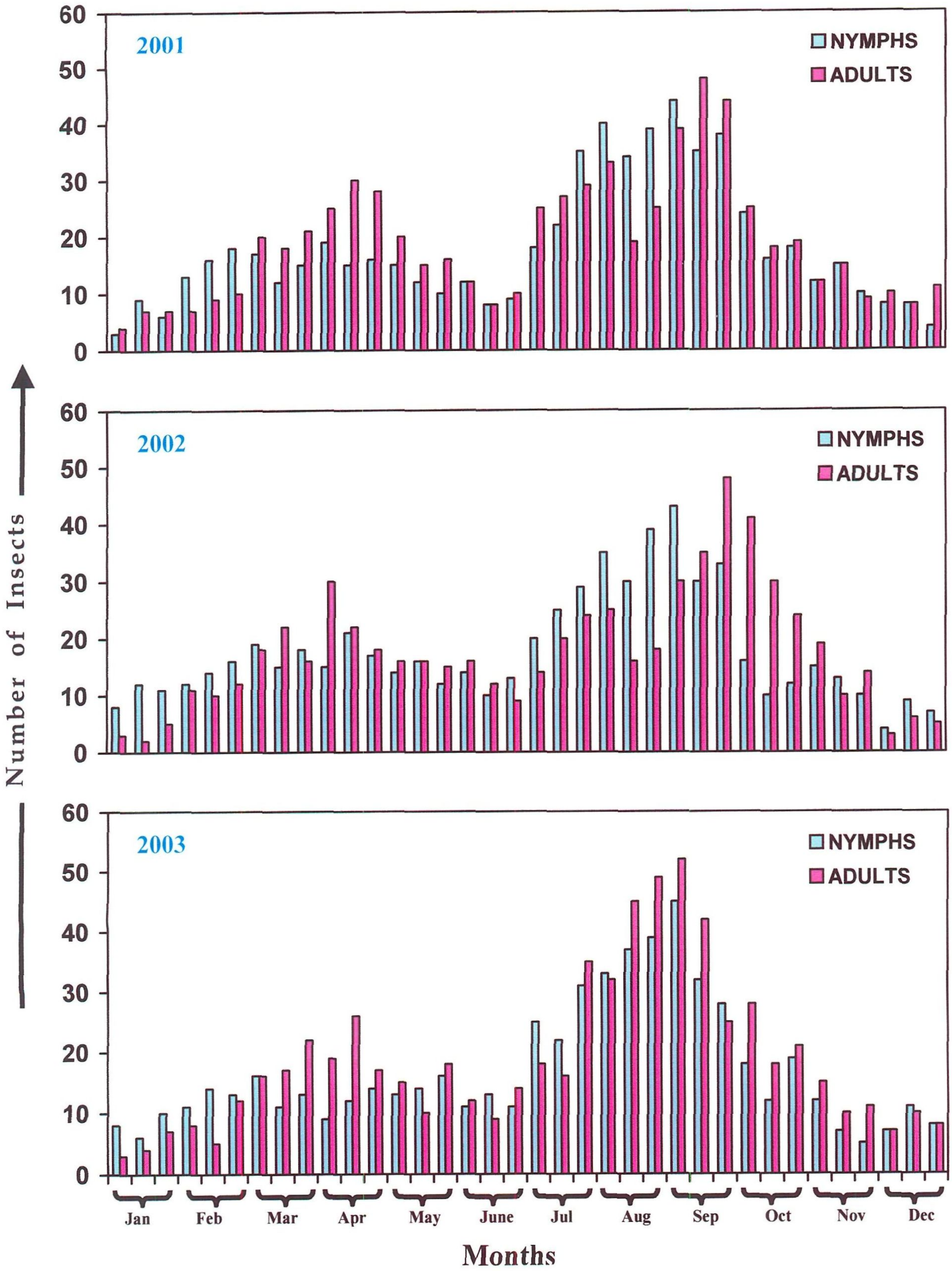


Fig. 80. Natural population estimation of *Phlaeoba infumata* Brunn.

of the males resulting in higher mortality among males. The stability of sex or survival potential of female sex was more pronounced than the male.

(c) Small scale movements:

During summer season of the years 2001–2003, a comprehensive study was made to explore the environmental factors influencing movements of this species in and around Aligarh, including all stages. Plot marking technique was adopted with special reference to available grass plot in the habitat which were divided into three categories namely:

1. grass between 5 – 6 inches
2. grass cut to within an inch to the ground
3. bare ground with an occasional tuft of long grass

These plots of the habitat were marked alternatively and the number of hoppers and adults entering in each alternative area was recorded. It was also recorded that the effect of slopes remain on the number of grasshoppers entering short grasses only, that more hoppers entered the short grasses at the bottom of the slope than at the top.

The small scale movements of the adults were confined to long and short grasses with intermittent and abrupt flights. The movements were also found to be affected by the day length. It was also critically observed that the male adults entering tall grasses leaving short while females were entering into short grasses as compared to tall grasses. All observations are based on visual inspections during the course of experimentation.

CHAPTER – IV

(C) ENVIRONMENTAL FACTORS

(i) TEMPERATURE:

The temperature gradient, increasing or decreasing, do affect the development of eggs, fecundity and the locomotory behaviour of the pest's biological stages. Therefore, the effect of temperature, as an environmental factor, has been studied under four categories, namely, eggs, fertility, hopper development and locomotary behvaiour.

(a) Effect of temperature on eggs:

The eggs were subjected to different temperatures and their incubation, hatching, hatchability was recorded. The temperature range was 10°C to 45°C while the relative humidity was maintained at 70±5%. Table 25 is self explanatory and shows that the temperature has a significant effect on eggs which is of an ecological importance in the biology of the species concerned.

(b) Effect of temperature on fertility:

The fertility is referred to the number of eggs hatched out of the total number of egg laid by a single female. In this case 750 eggs were incubated, out of which 650 eggs hatched at 35°C showing percentage of hatching to be as high as 86.67%. Such observations are of immense value in the biology of such pests where nothing is known (Table 25).

(c) Effect of temperature on hopper development:

The developmental process was affected when subjected to various temperatures ranging from 25°C to 45°C as evident from the rate and survival percentage of hoppers along with per day developmental rate as shown in Table 32.

(d) Effect of temperature on locomotory behaviour:

The locomotory behaviour is referred to the jumping and walking activities of the hoppers and the adults, and this was assessed on the basis of visual observations in rearing cages at different temperatures ranging from 10°C to 35°C. When the nymphal instars were released in cages maintained at 10°C, the locomotors activities were found slowest but when transferred to cages at 25°C, they showed increased activity. The brisk locomotory behaviour was recorded at 30°C to 35°C. Death occurred at 50°C.

Table: 32. Hopper duration, survival percentage, daily rate of development and growth index of *Phlaeoba infumata* Brunn. at different temperatures

Indices	Sex	Temperature (°C)		
		25	30	35
No. of hoppers observed		120	80	60
Number of hoppers attained adult stage		45	50	45
Survival percentage (n)		37.50	62.50	75
Average hopper development period (P) (days ± S.E.)	Male	89.40±1.77	58.33±1.61	46.13±1.36
	Female	114.00±2.91	74.50±1.76	55.87±1.47
Development of hoppers/ day (%± S.E.)	Male	1.12±0.02	1.73±0.03	1.80±0.05
	Female	0.88±0.02	1.35±0.03	1.80±0.05
Growth index (n/P)	Male	0.100	0.360	0.541
	Female	0.219	0.537	0.894

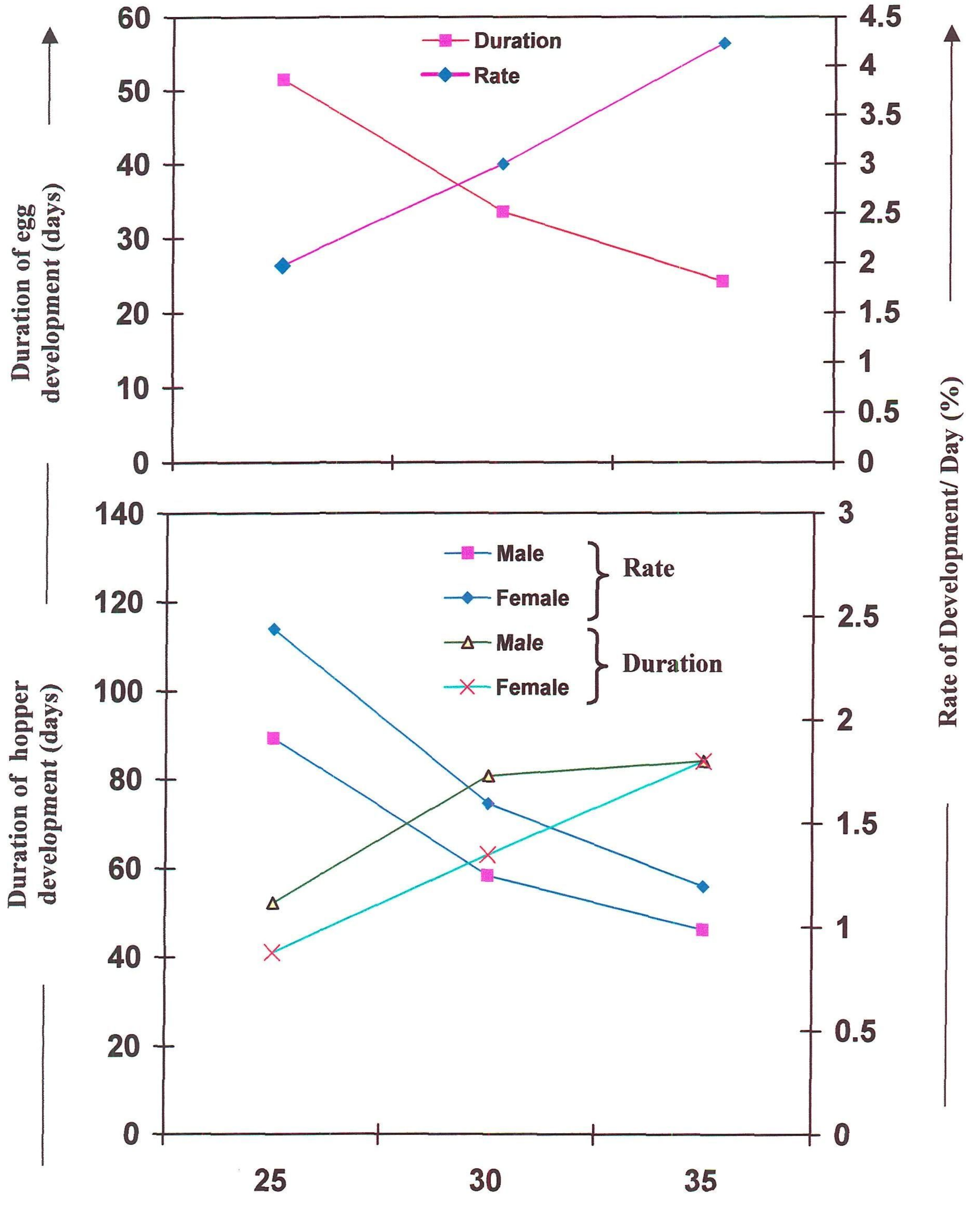


Fig.81. Graphs showing the effect of temperature upon duration (days) and rate of development per day (%) of eggs and hoppers of *Phlaeoba infumata* Brunn.

(C) ENVIRONMENTAL FACTORS

(ii) HUMIDITY:

It is already known that the relative humidity plays an important role in the physico–ecological behaviour of acridoids in general. However, nothing is known in this species. The present day study is based on wet and dry conditions created in terms of low and high humidity. The effect of such humidity of the soil, oviposition site and the development of hoppers and finally the fecundity was recorded.

(a) Effect of soil moisture on egg development:

The effect of soil moisture was studied under three conditions: where soil moisture was absent, present and in abundance or in excess.

In the present experiment, three egg–laying tubes with egg – pods were selected. One tube was not provided with any moisture while the second one was continuously provided with water and the third one was flooded. The result was that there was no hatching in the first and third tube and the second one gave normal hatchlings.

(b) Effect of moisture on the selection of oviposition sites:

The present species under study was tested with three different soils having variable moisture contents namely, completely dried, moist and flooded.

On releasing mature females, the egg–laying was done only in moist soil and the dry and the flooded soil was rejected by them.

(c) Effect of relative humidity on hopper development:

Like temperature, relative humidity is an ecological parameter, which affects the development process. Completely dry conditions like 5–10% R.H. show the least developmental progress by affecting general health and extending life span. The humidity ranging from 50–80% are preferred as evident from the normal developmental rate of the hoppers and timely life–cycle span. The excess of relative humidity also causes either developmental retardation or death of the individual.

(d) Effect of relative humidity on fertility:

The fertility in terms of percentage of hatching was found lowest at 10% R.H. and very high at 70–80% R.H. above that the fertility was at the lowest rate ever recorded.

(C) ENVIRONMENTAL FACTORS

(ii) FOOD:

(a)Effect of food plants on the development:

The effect of quality and quantity of food is of great significance in the development of various stages of insect during their life-cycle. The present experiment has been designed to test various food plants on the success and the rate of development of various stages of this species. Table 34, shows all such data regarding food plants, success of development, sexes of hopper development and the rate of development per day. The plants found in the habitat are listed and tested in the laboratory on the basis of sex and hopper development period. It was found that *Brassica oleracea* was most preferred by both sexes, which completed their life-cycles in 44.00 days (males) and 53.60 days (females) while feeding on *Andropogon adoratus* prolonged the life-cycle span up to 70.90 days in males and 87.90 days in females. It was thus considered as least preferred. The various effects on the hopper development of different food plants are given in the same table.

Table: 33. Effect of different food plants on the hopper development period and daily rate of development of *Phlaeoba infumata* Bruunn. reared at 35 ± 1 °C and 70 ± 5 % R.H.

Name of food plants	Sex	Hopper development period (Days)	Development of hoppers/ day (%)
Andropogon adoratus	Male	66.00–72.00 (70.90±0.34)	1.38–1.51 (1.44±0.04)
	Female	85.00–91.00 (87.90±0.75)	1.10–1.18 (1.16±0.07)
Cynodon dactylon	Male	55.00–65.00 (62.93±0.45)	1.54–1.72 (1.69±0.09)
	Female	61.00–70.00 (65.30±1.12)	1.43–1.64 (1.62±0.08)
Paspalum distichum	Male	41.00–44.00 (43.50±0.28)	2.27–2.43 (2.31±0.04)
	Female	70.00–76.00 (74.20±0.86)	1.31–1.43 (1.35±0.03)
Sorghum vulgare	Male	55.00–62.00 (59.10±0.67)	1.61–1.82 (1.70±0.06)
	Female	65.00–73.00 (71.60±0.93)	1.34–1.54 (1.42±0.02)
Saccharum officinarum	Male	65.00–71.00 (68.10±0.48)	1.41–1.54 (1.48±0.08)
	Female	85.00–92.00 (87.20±0.54)	1.09–1.18 (1.16±0.07)

Seteria verticillata	Male	63.00–68.00 (66.50±0.96)	1.47–1.59 (1.53±0.08)
	Female	76.00–81.00 (78.20±0.77)	1.23–1.31 (1.28±0.06)
Seteria glauca	Male	60.00–70.00 (68.00±0.98)	1.43–1.66 (1.58±0.09)
	Female	68.00–78.00 (75.70±1.03)	1.28–1.47 (1.38±0.03)
Panicum psilopodium	Male	48.00–54.00 (52.20±0.47)	1.85–2.08 (1.94±0.03)
	Female	55.00–62.00 (60.30±0.91)	1.61–1.82 (1.68±0.06)
Cyperus rotundus	Male	55.00–59.00 (56.10±0.38)	1.69–1.82 (1.88±0.08)
	Female	55.00–60.00 (58.80±0.61)	1.66–1.82 (1.80±0.06)
Lactuca sativa	Male	64.00–71.00 (65.70±0.29)	1.41–1.56 (1.53±0.07)
	Female	71.00–79.00 (77.80±0.46)	1.26–1.41 (1.29±0.09)
Brassica campestris	Male	53.00–64.00 (59.70±1.21)	1.56–1.88 (1.82±0.03)
	Female	66.00–78.00 (76.90±0.73)	1.28–1.51 (1.50±0.05)
Brassica oleracea var. botrytis	Male	42.00–48.00 (44.00±0.39)	2.08–2.38 (2.31±0.03)
	Female	51.00–58.00 (53.60±0.28)	1.72–1.96 (1.89±0.05)

Mean ± S.E. is given parentheses

(b) Effect of food plants on the survivability of nymphal stages:

The survival of various stages is also dependent on the quality and quantity of food plants available in the breeding ground. All the available food plants have been tested in the laboratory and the data are given in Table 33. Thirteen food plants were used and preference by insects in terms of sex, percentage of hoppers reaching adult stage (n), average hopper development period (P) and growth index (n/P) of this species are different for different plants. It is evident from the data that the highest percentage of hoppers successfully reaching adult stage while feeding on *Seteria glauca* and the lowest on *Saccharum officinarum*.

(c) Effect of food plants on adult survival and longevity:

The adults are resistant to various adverse effects of food and feeding in the natural breeding areas but when tested with six dominant food plants in the laboratory with respect to pre–copulation, pre–oviposition, oviposition and post–oviposition periods and longevity of adults of *Phlaeoba infumata* in terms of time at 35°C, it was found that *Seteria glauca* was the most preferred plant and *Saccharum officinarum* was found negatively affecting the longevity (Tables 25, 33 and Fig. 83).

Table: 34. Effect of different food plants on the growth, survival, hopper duration and daily rate of development of *Phlaeoba infumata* Brunn. reared at 35 ± 1 °C and 70±5 % R.H.

(10 replicates)

Food plants provided	Sex	Percent hoppers becoming adult (n)		Average hopper duration (days) (p)	'Development' of hoppers/ day (%)	Growth index (n/ p)
Andropogon adoratus	Male	33.09		70.90	1.44	0.46
	Female	14.69	47.78	87.90	1.16	0.16
Cynodon dactylon	Male	27.13		62.93	1.69	0.43
	Female	45.08	72.21	65.03	1.62	0.69
Paspalum distichum	Male	28.40		43.50	2.31	0.65
	Female	18.06	46.46			
Sorghum vulgare	Male	17.30		59.10	1.70	0.29
	Female	43.05	60.35	71.60	1.42	060
Saccharum officinarum	Male	8.72		68.10	1.48	0.12
	Female	11.60	20.32	87.20	1.16	0.13
Seteria verticillata	Male	28.50		66.50	1.53	0.42
	Female	14.50	43.00	78.20	1.28	0.18
Seteria glauca	Male	16.96		68.00	1.58	0.24
	Female	63.33	80.30	75.70	1.38	0.83

Panicum psilopodium	Male	21.23		52.20	1.94	0.41
	Female	40.47	61.70	60.30	1.68	0.67
Cyperus rotundus	Male	25.60		56.10	1.88	0.45
	Female	50.23	75.83	58.80	1.80	0.85
Lactuca sativa	Male	25.92		65.70	1.53	0.39
	Female	9.36	35.28	77.80	1.29	0.12
Brassica campestris	Male	14.15		59.70	1.82	0.23
	Female	10.51	24.66	76.90	1.50	0.15
Brassica oleracea	Male	29.79		44.00	2.31	0.67
var. botrytis	Female	18.90	48.69	53.60	1.89	0.35

The longevity of adults was found to be different with *Seteria glauca* recorded as 58.5 days in males and 63.0 days in females. It was highest while feeding on *Brassica oleracea* as 82.0 days in males and 88.7 days in females.

(d) Effect of food plants on fecundity:

The six species of food plants dominating the area were tested to find out if these plants affect the fecundity in females. The data in Table 36 show the average fecundity to be highest (140.72) with *Sorghum vulgare* and lowest (23.32) with *Brassica oleracea* var *botrytis*.

(e) Food preferences in nymphs:

The food preferences are indicative of nutritive preferential values of the food plants in a given area. The present experiment was designed to analyse the food plants tested in terms of accepted or rejected by the grasshopper or minimum and maximum survival potential of the same. This new approach to the nutritional ecology may be of applied nature for entomologists in general.

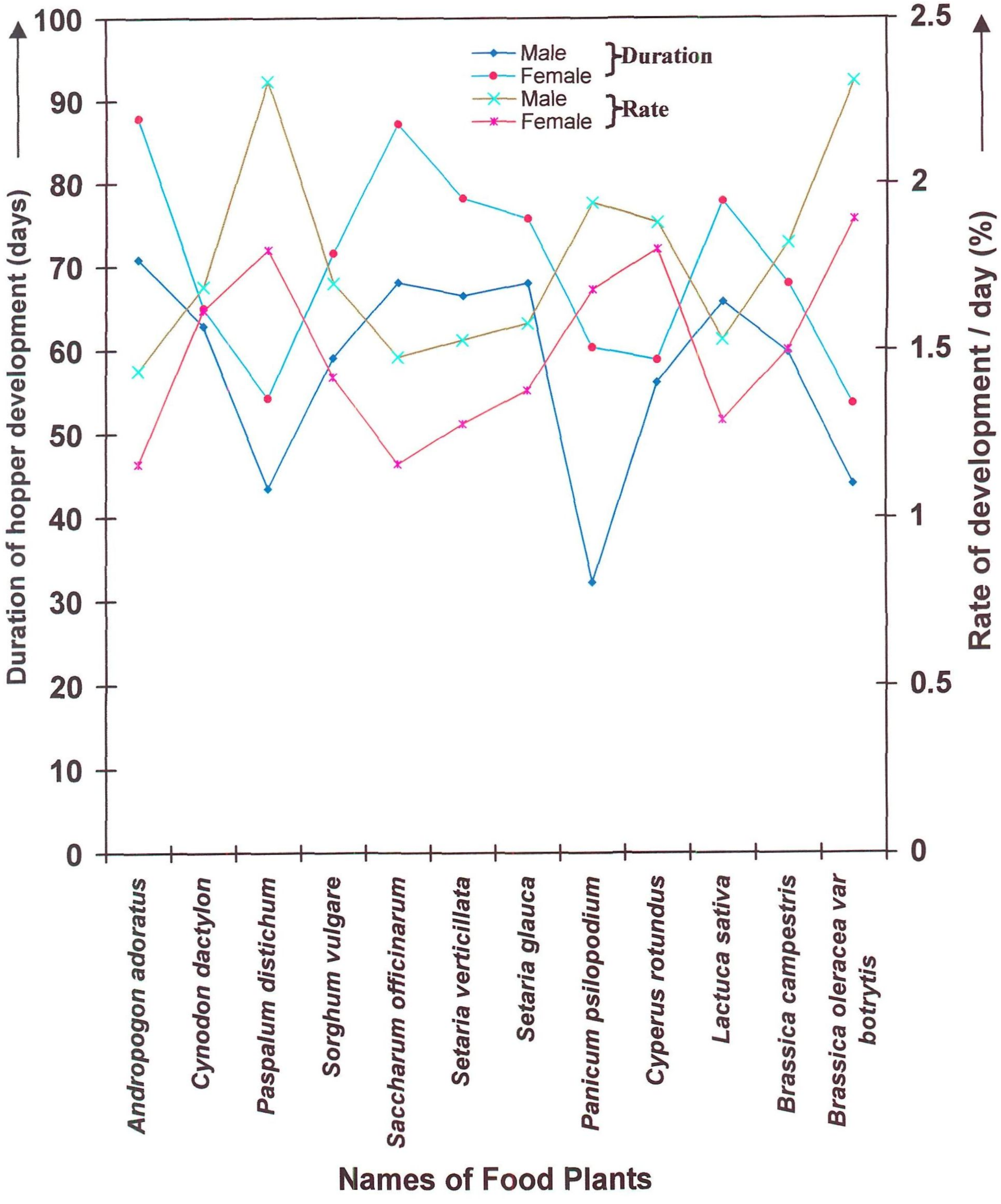


Fig.82. Effect of different food plants on the hopper duration and daily rate of development of *Phlaeoba infumata* Brunn.

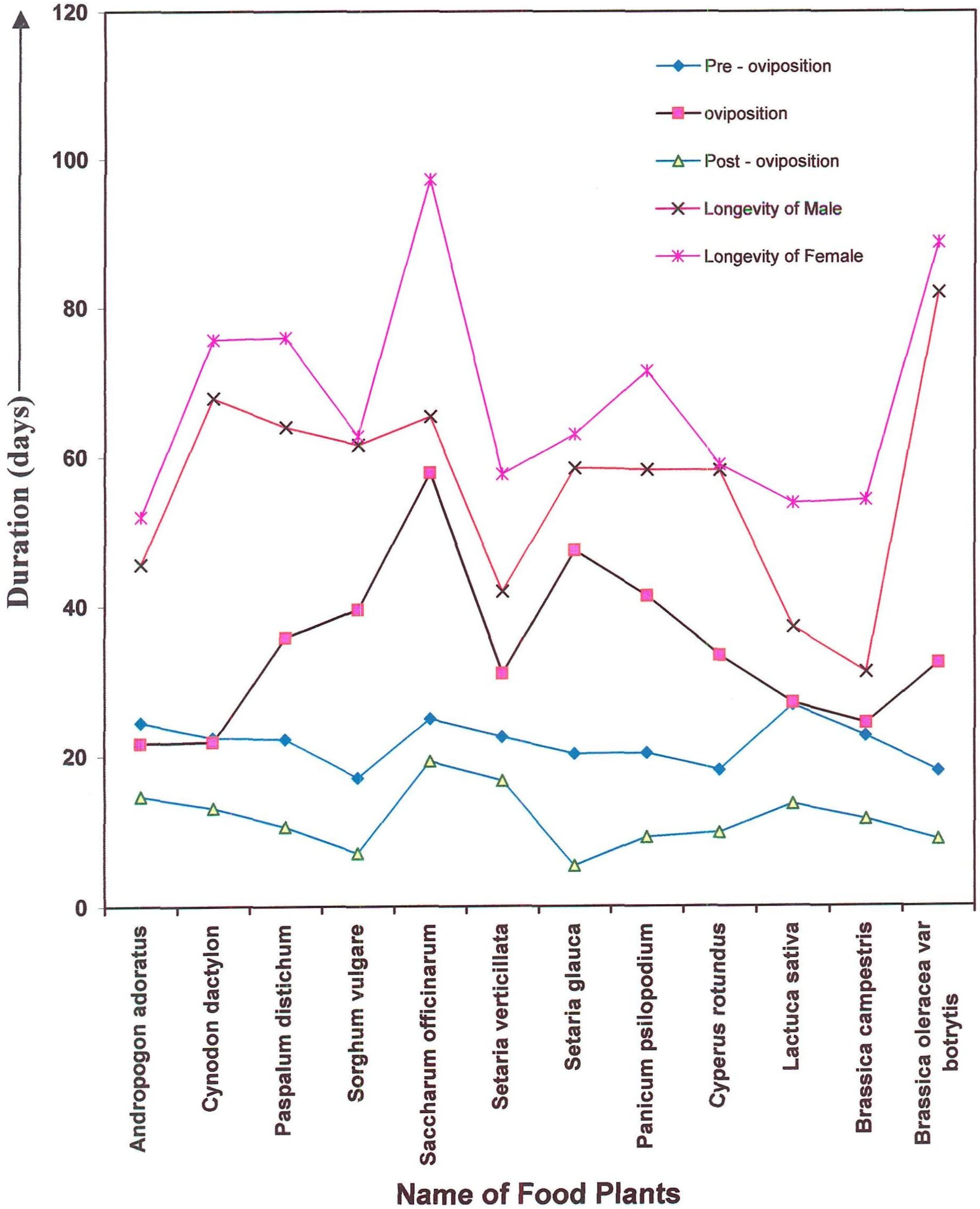


Fig.83. Effect of different food plants on the pre–oviposition, oviposition and post–oviposition periods and longevity of adults of *Phlaeoba infumata* Brunn.

Table: 35. Effect of different food plants on the pre–oviposition, oviposition, post–oviposition periods, egg pods/ female and longevity of adults of *Phlaeoba infumata* Brunn. reared at 35 ± 1 °C and 70 ± 5 % R.H.

(10 replicates, one pair in each replicates)

Food plants provided	Average pre – oviposition period (days ± S.E.)	Average oviposition period (days ± S.E.)	Average post – oviposition period (days ± S.E.)	Average egg–pods/ female (days ± S.E.)	Longevity of male (days ± S.E.)	Longevity of Female (days ± S.E.)
Andropogon adoratus	24.5±1.53	21.7±1.32	14.6±1.00	1.7±0.21	45.6±2.73	52.0±1.70
Cynodon dactylon	22.5±0.60	21.9±1.84	13.1±3.62	3.4±0.16	67.9±3.54	75.7±3.52
Paspalum distichum	22.3±0.44	35.8±2.04	10.6±1.11	3.4±0.16	64.0±1.61	76.0±2.45
Sorghum vulgare	17.1±0.41	39.6±1.61	7.1±0.53	6.5±0.22	61.6±1.14	62.8±2.31
Saccharum officinarum	25.0±0.87	57.9±4.51	19.3±1.02	4.3±0.26	65.4±2.20	97.3±3.99
Seteria verticillata	22.6±0.52	31.0±1.15	16.7±1.28	1.4±0.16	42.0±1.86	57.7± 2.07
Seteria glauca	20.3±2.51	47.5±2.85	5.4±1.07	6.4±0.34	58.5±4.83	63.0±1.85
Panicum psilopodium	20.4±0.72	41.4±1.19	9.2±0.59	4.4±0.16	58.3±2.36	71.5±0.85
Cyperus rotundus	18.1±0.72	33.4±2.25	9.8±0.61	5.6±0.16	58.2±1.20	59.0±0.86
Lactuca sativa	26.8±0.76	27.1±1.10	13.6±0.70	0.6±0.16	37.2±1.43	53.9±2.14
Brassica campestris	22.7±0.67	24.4±0.73	11.6±0.37	2.2±0.13	31.2±2.48	54.3±1.97
Brassica oleracea var. botrytis	18.0±2.56	32.4±1.77	8.9±0.23	1.4±0.22	82.0±3.59	88.7±0.00

Table: 36. Effect of different food plants on the pre–oviposition, oviposition, post–oviposition periods, egg pods/ female and longevity of adults of *Phlaeoba infumata* Brunn. reared at 35 ± 1 °C and 70 ± 5 % R.H.

(10 replicates, one pair in each replicates)

Food plants provided	No. of Females	Total egg – pods	Average egg–pods/ female (days ± S.E.) (a)	Total egg – pods laid	Average eggs/ egg – pod (± S.E.) (b)	Average fecundity (a×b)
Panicum psilopodium	25	110	4.4±0.16	2420	21.66±0.85	95.30
Cyperus rotundus	25	140	5.6±0.16	3380	24.65±0.72	138.04
Seteria glauca	25	160	6.4±0.34	3164	19.86±0.81	127.10
Sorghum vulgare	25	163	6.5±0.32	3467	21.65±0.99	140.72
Saccharum officinarum	25	108	4.3±0.26	2140	19.92±0.91	85.65
Cynodon dactylon	25	85	3.4±0.16	1476	17.41±0.42	59.19
Brassica oleracea var. botrytis	25	35	1.4±0.22	580	16.66±0.98	23.32
Brassica campestris	25	55	2.2±0.13	1276	23.34±0.81	51.35

CHAPTER – IV

(D) MORPHOMETRICS AND GREGARIOUS BEHAVIOUR

The present study on morphometrics of the hoppers and adults of this species is on the same pattern as was done in case of *Acrida exaltata*. All the parameters as well as body part indices taken for adults are same. In this species, all the 21 parameters, both in males as well in females were found statistically significant (Tables 37–40).

The comparative account of body part measurements is given in Tables 37–43, summarizing the stability and gradual developmental ratios among body parts, which represent mathematical progression in various components. All the measurements were made on 30 males and 30 females in isolated and crowded conditions.

It is evident from the results that the significant changes in some body parts under stress of crowding have occurred and show a definite tendency of gregariousness and phase formation attitude. These findings are very significant taking into account the polymorphic behaviour of this species.

(a) Isolation:

The body parts of all the nymphal instars measured while in isolation are comparable to that of individuals in crowding conditions and thus show a definite and marked difference in various parameters in morphometrics (Tables 37, 38).

(b) Crowding:

On few occasions in nature and on many occasions in the laboratory, the aggregation of nymphal instars and adults were recorded. An experimental batch of aggregating nymphal instars and adults were subjected to morphometrical analysis of body parts with two different sexes and tabulated in Tables 37, 38 depicting a significant change during such gregarious conditions. Of all 21 indices, some have shown significant morphometrical changes in both the sexes. These changes were prominent in length and width of body, width of vertex between the eyes, maximum width of head, langth and maximum width of pronotum, length of sternum, span of body with elytron, width of wing and hind femur. Standard deviations were calculated in both crowded and isolated conditions which support the basic apprehension that the species under study is a polymorphic and gregarious in nature.

(c) Colour changes:

The natural colour of this species is metallic or lustrous in appearance with many other combinations of colours. The normal pigmentation changes according to the age of the instar. The detailed account comparing with *Acrida exaltata* has already been given in Chapter – IV, Part – I, D (c) (Fig. 8 B).

(d) Swarming:

The temporary gregarization and discontinuous aggregation activity of this species was observed on many occasions. These preliminary observations have shown differences in size and colours and are mentioned in Chapter – IV, Part – I, D (d).

(e) Band formation:

In the early instar hoppers the primary grouping has been a common feature and previously was recorded in 1985 leading to a hypothesis that this species definitely linked with those acridoids having occasional gregarization. Recordings are mentioned with *Acrida exaltata* in Chapter – IV, Part – I, D (e).

(f) Instinctive behaviour:

The occasional gregarization seems to be instinctive because it is repeated frequently leaving temporal conditions aside. This instinct is linked with outbreaks of this species. This is not found when hatchings are poor and the species found numerically at the lowest ebb. Both the species under study have shown primary swarming, band formation and instinctive gregarious behaviour because they are sharing some ecological habitat and almost similar feeding and biological habits.

Table: 37. Means, standard errors and standard deviations of crowded and isolated adults of *Phlaeoba infumata* Brunn.

(30 replicates)

MALES

No.	Indices	Symbols	Mean and standard error		Standard deviation	
			Crowded	Isolated	Crowded	Isolated
1	Length of body	L	20.86±0.12	19.88±0.20	0.63	0.17
2	Width of body	b	03.72±0.04	03.44±0.02	0.19	0.12
3	Length of pronotum	P	03.70±0.03	03.82±0.05	0.16	0.27
4	Height of pronotum	H	03.15±0.03	03.12±0.02	0.17	0.11
5	Min. width of pronotum	Mp	02.20±0.03	02.15±0.01	0.14	0.06
6	Max. width of pronotum	Mx	02.49±0.02	02.53±0.01	0.12	0.06
7	Length of sternum	St	05.05±0.01	04.91±0.03	0.35	0.18
8	Span of body with elytron	SE	40.69±0.40	40.98±0.39	2.17	1.14
9	Length of elytron	E	19.17±0.18	19.08±0.18	0.99	0.98
10	Width of elytron	e	02.66±0.02	02.69±0.03	0.12	0.14
11	Length of wing	W	17.20±0.19	17.38±0.19	1.05	0.06
12	Width of wing	w	07.53±0.08	07.19±0.06	0.45	0.34
13	Length of anterior femur	AF	03.27±0.03	03.18±0.05	0.18	0.29
14	Length of middle femur	MF	03.64±0.01	03.96±0.04	0.22	0.22
15	Length of hind femur	F	12.42±0.10	12.38±0.86	0.57	1.74
16	Width of hind femur	f	02.35±0.02	02.47±0.03	0.09	0.16
17	Width of vertex between eyes	V	01.01±0.01	01.06±0.01	0.04	0.05
18	Vertical diameter of eye	O	01.78±0.01	01.86±0.02	0.06	0.11
19	Horizontal diameter of eye	Oh	01.26±0.01	01.32±0.01	0.03	0.06
20	Width of head	C	02.69±0.02	02.67±0.02	0.11	0.11
21	Length of antenna	A	08.40±0.02	08.73±10.12	0.47	0.64

Table: 38. Means, standard errors and standard deviations of crowded and isolated adults of *Phlaeoba infumata* Brunn.

(30 replicates)

FEMALES

No.	Indices	Symbols	Mean and standard error		Standard deviation	
			Crowded	Isolated	Crowded	Isolated
1	Length of body	L	29.20±0.30	27.77±0.22	1.66	1.20
2	Width of body	b	05.27±0.07	04.88±0.06	0.39	0.31
3	Length of pronotum	P	05.19±0.05	05.27±0.07	0.30	0.38
4	Height of pronotum	H	04.45±0.04	04.39±0.05	0.21	0.28
5	Min. width of pronotum	Mp	03.21±0.04	03.18±0.04	0.20	0.20
6	Max. width of pronotum	Mx	03.50±0.03	03.70±0.04	0.16	0.20
7	Length of sternum	St	06.97±0.07	07.13±0.07	0.38	0.37
8	Span of body with elytron	SE	53.44±0.49	53.69±0.45	2.68	2.47
9	Length of elytron	E	25.00±0.25	24.92±0.26	1.35	1.42
10	Width of elytron	e	03.60±0.04	03.59±0.08	0.22	0.46
11	Length of wing	W	22.97±0.22	23.21±0.22	1.18	1.18
12	Width of wing	w	10.13±0.11	09.88±0.13	0.61	0.72
13	Length of anterior femur	AF	04.24±0.04	04.43±0.04	0.21	0.23
14	Length of middle femur	MF	04.87±0.06	05.08±0.05	0.33	0.29
15	Length of hind femur	F	16.48±0.18	16.60±0.13	0.98	1.70
16	Width of hind femur	f	03.08±0.03	03.08±0.03	0.17	0.17
17	Width of vertex between eyes	V	01.42±0.01	01.47±0.01	0.07	0.06
18	Vertical diameter of eye	O	02.17±0.02	02.17±0.03	0.08	0.15
19	Horizontal diameter of eye	Oh	01.56±0.01	01.54±0.01	0.05	0.07
20	Width of head	C	03.94±0.03	03.92±0.05	0.15	0.26
21	Length of antenna	A	08.28±0.11	08.32±0.12	0.61	0.65

Table: 39. Differences between means of body parts measurements for adults of *Phlaeoba infumata* Brunn.

(30 replicates)

Males

No.	Indices	Symbols	Crowded – Isolated			
			Difference	T	d.f.	P
1	Length of body	L	+0.98	4.08	28	< 0.01
2	Width of body	b	+0.28	7.00	28	< 0.01
3	Length of pronotum	P	–0.12	2.40	28	< 0.05
4	Height of pronotum	H	+0.03	0.83	28	< 0.05
5	Min. width of pronotum	Mp	+0.05	1.85	28	< 0.05
6	Max. width of pronotum	Mx	–0.04	3.64	28	< 0.01
7	Length of sternum	St	+0.14	1.97	28	< 0.05
8	Span of body with elytron	SE	–0.29	0.52	28	< 0.05
9	Length of elytron	E	+0.09	2.82	28	< 0.05
10	Width of elytron	e	–0.03	0.90	28	< 0.05
11	Length of wing	W	–0.18	0.66	28	< 0.05
12	Width of wing	w	+0.34	3.33	28	< 0.01
13	Length of anterior femur	AF	+0.09	1.45	28	< 0.05
14	Length of middle femur	MF	–0.32	0.04	28	< 0.05
15	Length of hind femur	F	+0.04	0.57	28	< 0.05
16	Width of hind femur	f	–0.12	3.64	28	< 0.01
17	Width of vertex between eyes	V	–0.05	4.55	28	< 0.01
18	Vertical diameter of eye	O	–0.08	3.64	28	< 0.01
19	Horizontal diameter of eye	Oh	–0.06	5.00	28	< 0.05
20	Width of head	C	+0.02	0.71	28	< 0.05
21	Length of antenna	A	–0.33	2.29	28	< 0.05

Table: 40. Differences between means of body parts measurements for adults of *Phlaeoba infumata* Brunn.

(30 replicates)

Females

No.	Indices	Symbols	Crowded – Isolated			
			Difference	T	d.f.	P
1	Length of body	L	+1.43	3.86	28	< 0.01
2	Width of body	b	+0.39	1.50	28	< 0.05
3	Length of pronotum	P	–0.08	1.00	28	< 0.05
4	Height of pronotum	H	+0.06	0.95	28	< 0.05
5	Min. width of pronotum	Mp	+0.03	0.59	28	< 0.05
6	Max. width of pronotum	Mx	–0.20	4.35	28	< 0.01
7	Length of sternum	St	–0.16	1.67	28	< 0.05
8	Span of body with elytron	SE	–0.25	0.38	28	< 0.05
9	Length of elytron	E	+0.08	0.22	28	< 0.05
10	Width of elytron	e	+0.01	0.11	28	< 0.05
11	Length of wing	W	–0.24	0.79	28	< 0.05
12	Width of wing	w	+0.25	1.45	28	< 0.05
13	Length of anterior femur	AF	–0.19	3.39	28	< 0.01
14	Length of middle femur	MF	–0.21	2.62	28	< 0.05
15	Length of hind femur	F	–0.12	2.79	28	< 0.05
16	Width of hind femur	f	+0.00	0.05	28	< 0.05
17	Width of vertex between eyes	V	–0.05	3.13	28	< 0.01
18	Vertical diameter of eye	O	+0.00	0.16	28	< 0.05
19	Horizontal diameter of eye	Oh	+0.02	1.33	28	< 0.05
20	Width of head	C	+0.02	0.37	28	< 0.05
21	Length of antenna	A	–0.04	0.25	28	< 0.05

Table: 41. Mean ratios in isolated and crowded conditions for adults of *Phlaeoba infumata* Brunn.

(30 replicates)

S.No.	Ratios	Symbols	Mean and Standard error				Standard deviation			
			Males		Females		Males		Females	
			Crowded	Isolated	Crowded	Isolated	Crowded	Isolated	Crowded	Isolated
1	Length of Pronotum to Max. width of head	P/C	1.38±0.01	1.43±0.02	1.32±0.01	1.35±0.02	0.04	0.11	0.05	0.10
2	Length of elytron to Length of hind femur	E/F	1.53±0.01	1.45±0.02	1.52±0.01	1.50±0.02	0.06	0.10	0.06	0.09
3	Length of hind femur to Max. width of head	F/C	4.63±0.03	4.96±0.06	4.19±0.03	4.25±0.06	0.18	0.30	0.17	0.34
4	Length of hind femur to Length of pronotum	F/P	3.36±0.02	3.47±0.06	3.18±0.04	3.16±0.04	0.09	0.31	0.11	0.20
5	Vertical diameter of eye to Width of vertex	O/V	1.76±0.01	1.76±0.02	1.53±0.01	1.48±0.02	0.07	0.11	0.08	0.13
6	Length of hind femur to Width of vertex	F/V	12.28±0.08	12.48±0.15	11.62±0.11	11.32±0.11	0.43	0.80	0.60	0.59

Table: 42. Differences between means of ratios in isolated and crowded conditions for adults of *Phlaeoba infumata* Brunn.

(30 replicates)

S.No.	Ratios	Symbols	Crowded males – Isolated males				Crowded females – Isolated females			
			Difference	t	d..f.	P	Difference	t	d..f.	P
1	Length of Pronotum to Max. width of head	P/C	–0.05	2.38	28	0.05	–0.03	1.50	28	< 0.05
2	Length of elytron to Length of hind femur	E/F	+0.08	3.81	28	0.01	+0.02	1.05	28	< 0.05
3	Length of hind femur to Max. width of head	F/C	–0.33	5.24	28	0.01	–0.06	0.87	28	< 0.05
4	Length of hind femur to Length of pronotum	F/P	–0.11	1.90	28	0.05	–0.04	0.39	28	< 0.05
5	Vertical diameter of eye to Width of vertex	O/V	+0.002	0.09	28	0.05	+0.05	11.11	28	< 0.01
6	Length of hind femur to Width of vertex	F/V	–0.20	1.21	28	0.05	+0.30	1.96	28	< 0.05

Table: 43. Differences between means of ratios in isolated and crowded conditions for adults of *Phlaeoba infumata* Brunn.

(30 replicates)

S.No.	Ratios	Symbols	Crowded males – Crowded females				Isolated males – Isolated females			
			Difference	t	d..f.	P	Difference	T	d..f.	P
1	Length of Pronotum to Max. width of head	P/C	+0.06	5.00	28	0.01	+0.08	2.96	28	< 0.05
2	Length of elytron to Length of hind femur	E/F	+0.01	0.67	28	0.05	–0.05	2.08	28	< 0.05
3	Length of hind femur to Max. width of head	F/C	+0.44	9.78	28	0.01	+0.71	8.65	28	< 0.01
4	Length of hind femur to Length of pronotum	F/P	+0.24	9.47	28	0.01	+0.31	4.63	28	< 0.01
5	Vertical diameter of eye to Width of vertex	O/V	+0.22	11.58	28	0.01	+0.27	8.71	28	< 0.01
6	Length of hind femur to Width of vertex	F/V	+0.66	4.93	28	0.01	+1.16	6.41	28	< 0.01

MISCELLANEOUS OBSERVATIONS

CHAPTER – V

MISCELLANEOUS OBSERVATIONS

During the biological studies on these two species, found in close association, certain miscellaneous observations were also recorded.

(a) Effect of isolated and crowded conditions on the viability of eggs, egg – pods, and incubation periods:

The two conditions were designed during rearing of these species namely isolated and crowded and the parameters were taken in order to find negative or positive impact. The data thus obtained for *Acrida exaltata* and *Phlaeoba infumata* (Table 44) are self explanatory showing definite influence of crowding on such parameters. It is interesting to note that in these solitary grasshoppers the crowding plays an important ecological role by showing the effects on the eggs, egg–pods, and incubation period. Number of egg–pods laid by isolated females to an average of 3.68 while in crowded females the number has been reduced to an average of 3.12 in case of *Acrida exaltata* and in case of *Phlaeoba infumata* the egg–pods laid by isolated females to an average of 3.28 and in crowded females average egg–pods reduced to 3.00.

Table: 44. Effect of isolated and crowded conditions on the viability of egg–pods and eggs of *Acrida exaltata* Walk. and *Phlaeoba infumata* Brunn.

Species	Rearing conditions	Number of egg – pods kept for incubation	Number of viable egg–pods	Number of non–viable egg–pods	Percentage of viable egg–pods	Percentage of non–viable egg–pods	Percentage of eggs hatched (fertility ±S.E.)	Percentage of non – viable eggs (mortality ±S.E.)
Acrida exaltata Walk.	Isolated	70	50	20	71.43	28.57	56.03±2.98	43.97±2.98
	Crowded	80	62	18	77.50	22.50	72.24±2.29	27.76±2.29
Phlaeoba infumata Brunn.	Isolated	65	50	15	76.92	23.08	67.51±1.79	32.59±1.78
	Crowded	85	70	15	82.35	17.65	83.97±3.20	16.04± 3.20

Similarly the significant difference in viable egg–pods, percentage of viable egg–pods, fertility and mortality were found to be different in *Acrida exlatata* while in *Phlaeoba infumata* such differences were too significant. These observations were too indicates clearly that both the species are sensitive to isolated and crowded conditions. This phenomenon is very specific to permanently gregarious locust species.

(b) Effect of isolated and crowded conditions on the pre – copulation, pre – oviposition, oviposition, post oviposition and longevity of adults:

Another aspect of crowded and isolated conditions and their impact on various parameters of biology are shown in Table 45 for *Acrida exaltata* and *Phlaeoba infumata,* inferring that a slight change is found in pre–copulation and post–copulation periods. Both these species are found tending towards behavioural changes when subjected to two different conditions. The slight deviations are of much importance and are indicative of a hidden tendency of gregariousness at times, in these two species.

Table: 45. Pre–oviposition, oviposition, post–oviposition periods and longevity of Adults of *Acrida exaltata* Walk. and *Phlaeoba infumata* Brunn. under isolated and crowded conditions at 35±1 °C and 70±5 % R.H. and fed on grass, *Cynodon dactylon* Pers. leaves.

(10 replicates)

Species	Rearing conditions	Average pre–oviposition period (days ± S.E.)	Average–oviposition period (days ± S.E.)	Average post–oviposition period (days ± S.E.)	Average longevity (days ± S.E.)	
					Male	Female
Acrida exaltata Walk.	Isolated	16–39 (23.50±2.12)	14–26 (18.90±1.47)	1–17 (5.30±1.61)	16–55 (40.50±5.47)	42–62 (48.40±2.97)
	Crowded	14–30 (22.20±1.74)	12–22 (18.10±0.98)	1–15 (4.80±1.42)	14–45 (34.70±3.69)	35–52 (45.90±2.00)
Phlaeoba infumata Brunn.	Isolated	20–26 (22.50±0.60)	10–30 (21.90±1.84)	2–42 (13.10±3.62)	50–80 (67.90±3.54)	60–90 (75.70±3.52)
	Crowded	16–24 (20.30±2.79)	8–24 (19.30±1.63)	1–20 (8.30±1.53)	45–70 (58.00±2.92)	55–82 (72.70±2.82)

Similarly the significant difference in viable egg–pods, percentage of viable egg–pods, fertility and mortality were found to be different in *Acrida exlatata* while in *Phlaeoba infumata* such differences were too significant. These observations were too indicates clearly that both the species are sensitive to isolated and crowded conditions. This phenomenon is very specific to permanently gregarious locust species.

(b) Effect of isolated and crowded conditions on the pre – copulation, pre – oviposition, oviposition, post oviposition and longevity of adults:

Another aspect of crowded and isolated conditions and their impact on various parameters of biology are shown in Table 45 for *Acrida exaltata* and *Phlaeoba infumata*, inferring that a slight change is found in pre–copulation and post–copulation periods. Both these species are found tending towards behavioural changes when subjected to two different conditions. The slight deviations are of much importance and are indicative of a hidden tendency of gregariousness at times, in these two species.

Table: 45. Pre–oviposition, oviposition, post–oviposition periods and longevity of Adults of *Acrida exaltata* Walk. and *Phlaeoba infumata* Brunn. under isolated and crowded conditions at 35±1 °C and 70±5 % R.H. and fed on grass, *Cynodon dactylon* Pers. leaves.

(10 replicates)

Species	Rearing conditions	Average pre–oviposition period (days ± S.E.)	Average–oviposition period (days ± S.E.)	Average post–oviposition period (days ± S.E.)	Average longevity (days ± S.E.)	
					Male	Female
Acrida exaltata Walk.	Isolated	16–39 (23.50±2.12)	14–26 (18.90±1.47)	1–17 (5.30±1.61)	16–55 (40.50±5.47)	42–62 (48.40±2.97)
	Crowded	14–30 (22.20±1.74)	12–22 (18.10±0.98)	1–15 (4.80±1.42)	14–45 (34.70±3.69)	35–52 (45.90±2.00)
Phlaeoba infumata Brunn.	Isolated	20–26 (22.50±0.60)	10–30 (21.90±1.84)	2–42 (13.10±3.62)	50–80 (67.90±3.54)	60–90 (75.70±3.52)
	Crowded	16–24 (20.30±2.79)	8–24 (19.30±1.63)	1–20 (8.30±1.53)	45–70 (58.00±2.92)	55–82 (72.70±2.82)

(c) Effect of isolated and crowded conditions on the fecundity of females:

Adult females of both species under study, were subjected to isolated and crowded conditions and the total number of egg–pods laid, egg–pods per female, total number of eggs and average fecundity were calculated. In both cases the crowding does affect all the parameters, as is also seen in all locust species. Therefore, these observations (Table 46) are significant to determine the behaviour under crowded conditions.

(d) Effect of isolated and crowded conditions on survival percentage and hopper duration:

In this set of experiment, both the species show considerable resemblance in behaviour when put to crowding. However, *Phlaeoba infumata* was found to be more reactive in the crowded condition as compared to *Acrida exaltata* (Table 47). Number of hopper attained adult stage in *Phlaeoba infumata* was found to be 40 out of 50 (80%) in isolated condition while in crowded stage; it has gone to 55 out of 80 (68.75%). This ratio was found to be less in *Acrida exaltata* when in isolated condition but more in crowded stage.

Table: 46. Effect of isolated and crowded conditions on the fecundity of females of *Acrida exaltata* Walk. and *Phlaeoba infumata* Brunn.

Species	Rearing conditions	Number of females	Total number of egg – pods laid	Average number of egg–pods/ female ±S.E. (a)	Total number of eggs laid	Average number of eggs / egg–pod ±S.E. (b)	Average fecundity (a × b)
Acrida exaltata Walk.	Isolated	25	92	3.68±0.11	2263	25.09±0.96	92.33
	Crowded	25	78	3.12±0.12	1520	20.40±0.74	63.65
Phlaeoba infumata Brunn.	Isolated	25	82	3.28±0.01	1546	19.65±0.98	64.45
	Crowded	25	78	3.00±0.13	1258	17.59±0.94	52.77

Table: 47. Hopper duration and survival percentage of *Acrida exaltata* Walk. and *Phlaeoba infumata* Brunn. Fed on *Cynodon dactylon* Pers. leaves under isolated and crowded conditions at 35±1 °C and 75±5% R.H.

Species	Rearing conditions	Number of hoppers observed	Number of hoppers attained adult stage	Survival percentage	Average hopper duration (days±S.E.)	
					Male	Female
Acrida exaltata Walk.	Isolated	50	38	76	43.53±0.53	55.83±1.29
	Crowded	100	65	65	50.83±4.65	58.30±8.26
Phlaeoba infumata Brunn.	Isolated	50	40	80	46.13±1.36	55.87±1.47
	Crowded	80	55	68.75	62.93±2.62	65.03±2.49

(e) Effect of various food plants on the different body parts under crowded condition:

This experiment was designed during normal rearing of both sexes of these two species, taking into account twenty body parts and eleven food plants including the plant that is less preferred. The data on analysis have shown definite changes in body part measurements versus food plants as evident from tables 48–51.

During the ecological studies on *Acrida exaltata* and *Phlaeoba infumata* some amazing observations were also recorded pertaining to a new concept initiated by Rizvi (1985) as chromoecological behaviour being taken as bioindicator of environment and associated changes. Both acridoids have shown a particular colouration uniformly green or varying shades of brown and yellow colours and reddish or olive–brown, rather variable respectively. During ecological observations, both species have shown chromoecological behaviour representing various spectra in different stages of life when gregarizing occasionally. This condition was created as crowded in jars in laboratory and all life stages were observed and analysed by a dictionary of colours by Maerz and Paul (1950) [Figs. 84 (A, B, C), 85 (A, B, C) and 86]. It was emphatically observed that most of the colours were appeared on thoracic shield and more pronounced on pronotum. Among

Table: 48. Effect of food plants on the dimensions of body of *Acrida exaltata* Walk. reared under crowded condition

Male

Indices	Name of food plants										
	Cynodon dactylon	*Paspalum distichum*	*Sorghum vulgare*	*Saccharum officinarum*	*Setaria verticillata*	*Setaria glauca*	*Panicum psilopodium*	*Cyperus rotundus*	*Lactuca sativa*	*Brassica compestris*	*Brassica oleracea or botrytis*
Length of body	31.06±0.53	30.58±0.19	31.66±0.15	32.78±0.18	32.39±0.15	30.03±0.17	32.25±0.36	31.96±0.51	30.91±0.13	31.95±0.28	32.58±0.22
Width of body	3.57±0.09	3.38±0.01	3.58±0.01	3.73±0.02	3.75±0.01	3.59±0.02	3.73±0.04	3.78±0.05	3.49±0.08	3.73±0.02	3.79±0.02
Length of Pronotum	5.03±0.08	4.76±0.01	4.91±0.02	5.29±0.01	5.40±0.01	4.88±0.06	5.13±0.10	5.10±0.10	5.27±0.07	5.33±.06	5.36±0 10
Height of pronotum	2.73±0.06	2.48±0.02	2.58±0.01	3.29±0.14	2.91±0.01	2.57±0.01	2.82±0.07	2.88±0.03	2.67±0.02	2.94±0.01	2.96±0.01
Min. width of pronotum	2.29±0.02	2.73±0.01	2.12±0.01	2.13±0.01	2.26±0.01	2.05±0.01	2.18±0.04	2.24±0.02	2.12±0.02	2.16±0.01	2.23±0.01
Max. width of pronotum	2.79±0.03	2.57±0.01	2.56±0.01	2.66±0.01	2.81±0.01	2.46±0.02	2.61±0.04	2.74±0.04	2.59±0.02	2.77±0.01	2.84±0.01
Length of pronotum	6.06±0.11	5.76±0.01	6.01±0.03	6.45±0.02	6.44±0.01	5.96±0.04	6.34±0.08	6.33±0.10	5.85±0.06	6.44±0.01	6.47±0.03
Span of body with elytron	54.32±1.03	50.99±0.14	54.51±0.13	56.93±0.20	56.25±0.07	55.79±0.62	55.06±0.01	55.44±1.16	53.39±0.12	55.60±0.16	56.76±0.17
Length of elytron	25.76±0.52	24.28±0.06	25.46±0.18	27.16±0.16	26.66±0 12	24.91±0.24	26.15±0.53	26.24±0.55	25.17±0.11	26.65±0.15	26.72±0.20

Width of elytron	2.85±0.06	2.66±0.01	2.86±0.01	2.77±0.01	2.93±0.01	2.87±0.04	2.82±0.06	2.85±0.07	2.83±0.11	2.80±0.08	2.78±0.01
Length of wing	23.22±0.36	21.30±0.19	22.26±0.20	24.22±0.06	24.57±0.11	22.40±0.36	22.94±0.50	23.40±0.42	22.53±0.11	23.75±0.19	24.71±0.16
Width of wing	9.58±0.34	9.40±0.04	9.51±0.03	10.31±0.06	10.24±0.06	9.88±0.12	9.78±0.25	10 32±0.21	9.39±0.05	10.23±0.07	10.49±0.12
Length of ant. femur	5.06±0.10	4.57±0.04	4.82±0.03	5.47±0.01	5.43±0.01	4.76±0.05	4.98±0.09	5.14±0.12	4.71±0 03	5.44±0.02	5.46±0.01
Length of middle femur	6.22±0.14	5.75±0.03	6.19±0.03	6.33±0.01	6.54±0.01	5.70±0.07	6.25±0.10	6.38±0.15	6.29±0 07	6.48±0.01	6.60±0.02
Length of hind femur	19.48±0.43	17.97±0.13	18.56±0.11	20.58±0.11	20.56±0.12	18 16±0.23	20.04±0.38	19.41±0.58	18.98±0.12	20.03±0.22	21.13±0.24
Width of hind femur	1.32±0.04	1.28±0.01	1.23±0.01	1.56±0.01	1.36±0.01	1.33±0.01	1.39±0.04	1.38±0.04	1.33±0.01	1.38±0.01	1.39±0.02
Width of vertex between eyes	0.94±0.02	0.87±0.01	0.93±0.01	0.95±0.01	0.98±0.01	0.91±0.01	0.99±0.02	0.99±0.01	0.97±0.01	0.96±0.01	0.98±0.01
Vertical diameter of eye	2.62±0.04	2.45±0.01	2.59±0.01	2.73±0.01	2.59±0.01	2.50±0.01	2.67±0.01	2.59±0.03	2.58±0.01	2.58±0.01	2.63±0.01
Horizontal diameter of eye	1.26±0.02	1.22±0.01	1.23±0.01	1.24±0.01	1.33±0.01	1.20±0.01	1.30±0.01	1.32±0.01	1.23±0.01	1.29±0.01	1.33±0.01
Width of head	2.75±0.03	2.59±0.01	2.69±0.01	2.64±0.01	2.57±0.01	2.58±0.01	2.70±0.02	2.70±0.03	2.59±0.01	2.49±0.02	2.59±0.03
Length of antenna	11.24±0.32	10.84±0.16	11.29±0.16	10.47±0.11	12.30±0.07	10.36±0.25	11.79±0.24	11.86±0.32	11.57±0.15	12.41±0.10	12.46±0.14

Table: 49. Effect of food plants on the dimensions of body of *Acrida exaltata* Walk. reared under crowded condition

Female

Indices	Name of food plants										
	Cynodon dactylon	*Paspalum distichum*	*Sorghum vulgare*	*Saccharum officinarum*	*Setaria verticillata*	*Setaria glauca*	*Panicum psilopodium*	*Cyperus rotundus*	*Lactuca sativa*	*Brassica compestris*	*Brassica oleracea or botrytis*
Length of body	48.45±0.63	49.62±0.12	51.02±0.25	50.22±0.18	42.94±0.21	49.19±0.22	50.42±0.53	46.01±0.22	41.39±0.12	44.93±0.22	44.89±0.12
Width of body	5.82±0.11	6.40±0.02	6.27±0.01	5.73±0.12	5.75±0.02	6.51±0.06	6.45±0.05	5.74±0.12	5.57±0.01	5.65±0.04	6.15±0.023
Length of Pronotum	7.84±0.11	7.89±0.05	8.12±0.09	8.18±0.01	7.06±0.01	8.41±0.04	8.57±0.07	7.60±0.06	6.45±0.02	7.38±0.05	7.88±0.05
Height of pronotum	4.43±0.08	4.32±0.09	4.56±0 02	5.07±0.01	3.89±0.02	4.36±0.05	4.78±0.09	4.27±0.01	3.85±0.05	4.27±0.03	4.42±0.01
Min. width of pronotum	3.77±0.06	3.48±0.01	3.75±0.01	3.70±0.02	3.18±0.01	3.73±0.03	3.91±0.02	3.57±0.01	3.02±0.02	3.68±0.01	3.61±0.07
Max. width of pronotum	4.37±0.11	4.15±0.03	4.33±0.02	4.16±0.02	3.69±0.01	4.52±0.06	4.52±0.02	4.27±0.04	3.67±0.02	4.06±0.02	4.29±0.01
Length of pronotum	9.22±0.16	9.54±0.02	10.00±0.11	9.17±0.01	8.50±0.09	9.82±0.06	10.23±0.04	9.30±0.05	8.12±0.02	8.94±0.02	9.29±0.01
Span of body with elytron	83.92±0.89	86.31±0.17	86.45±0.33	86.08±0.33	77.57±0.08	87.38±0.35	91.44±1.07	80.87±1.53	73.80±0.54	79.73±0.18	85.61±0.17
Length of elytron	39.79±0.45	41.01±0.19	41.32±0.16	40.87±0.18	36.69±0.15	41.84±0.18	43.54±0.47	40.84±1.12	34.79±0.11	37.66±0.19	41.41±0.09

Width of elytron	4.13±0.07	4.58±0.01	4.76±0.06	4.41±0.04	3.67±0.01	4.55±0.01	4.64±0.03	4.50±0.05	3.68±0.01	4.03±0.01	4.39±0.07
Length of wing	35.55±0.72	36.85±0.12	38.00±0.14	36.60±0.12	30.54±0.10	36.79±0.14	39.34±0.20	36.06±0.49	31.22±0.19	34.23±0.19	37.59±0.12
Width of wing	14.55±0.26	15.22±0.03	14.68±0.14	14.31±0.06	12.12±0.12	14.06±0.12	14.84±0.24	15.03±0.18	11.83±0.18	12.88±0.18	15.04±0.17
Length of ant. femur	6.89±0.12	7.33±0.03	7.20±0.08	7.24±0.01	6.05±0.01	7.26±0.01	7.51±0.06	6.70±0.08	6.32±0.01	6.61±0.03	6.59±0.04
Length of middle femur	9.29±0.20	9.06±0.01	9.36±0.06	9.49±0.01	8.11±0.03	9.32±0.04	10.08±0.03	8.76±0.01	8.65±0.02	8.57±0.01	8.55±0.12
Length of hind femur	29.55±0.53	29.21±0.16	29.64±0.27	29.93±0.18	25.49±0.10	30.17±0.21	32.24±0.22	27.30±0.72	23.23±0.19	26.86±0.02	27.89±0.21
Width of hind femur	2.05±0.05	2.09±0.02	2.17±0.02	2.17±0.02	1.87±0.01	2.22±0.01	2.23±0.03	1.89±0.01	1.83±0.01	2.15±0.01	1.98±0.01
Width of vertex between eyes	1.25±0.02	1.15±0.03	1.35±0.02	1.32±0.01	1.13±0.01	1.30±0.01	1.32±0.01	1.36±0.01	1.13±0.01	1.23±0.01	1.29±0.01
Vertical diameter of eye	3.25±0.03	3.03±0.01	3.56±0.01	3.48±0.01	3.08±0.01	3.14±0.01	3.43±0.02	3.28±0.03	3.15±0.03	3.22±0.01	3.28±0.01
Horizontal diameter of eye	1.55±0.02	1.44±0.01	1.63±0.01	1.63±0.01	1.50±0.01	1.50±0.01	1.61±0.02	1.59±0.01	1.63±0.01	1.67±0.01	1.53±0.01
Width of head	4.62±0.07	4.63±0.01	4.66±0.01	4.54±0.07	4.06±0.01	4.66±0.01	4.86±0.03	4.39±0.04	3.78±0.01	4.29±0.01	4.42±0.01
Length of antenna	14.00±0.30	15.58±0.07	16.53±0.18	15.46±0.11	12.37±0.13	16.01±0.10	16.17±0.18	12.64±0.27	14.41±0.08	12.55±0.07	14.25±0.07

Table: 50. Effect of food plants on the dimensions of body of *Phlaeoba infumata* Brunn. reared under crowded condition

Male

Indices	Name of food plants										
	Cynodon dactylon	*Paspalum distichum*	*Sorghum vulgare*	*Saccharum officinarum*	*Setaria verticillata*	*Setaria glauca*	*Panicum psilopodium*	*Cyperus rotundus*	*Lactuca sativa*	*Brassica compestris*	*Brassica oleracea or botrytis*
Length of body	20.90±0.22	20.08±0.21	20.64±0.21	21.08±0.30	20.28±0.21	20.92±0.28	21.60±0.16	21.31±0.22	19.33±0.12	19.79±0.16	20.16±0.29
Width of body	3.78±0.07	3.48±0.02	3.75±0.05	3.67±0.01	3.52±0.02	3.68±0.06	3.73±0.02	3.94±0.03	3.64±0.04	3.88±0.07	3.89±0.03
Length of pronotum	3.76±0.07	3.41±0.02	3.68±0.05	3.76±0.01	3.44±0.01	3.72±0.05	3.76±0.01	4.04±0.04	3.64±0.04	3.89±0.06	3.86±0.04
Height of pronotum	3.15±0.05	3.08±0.02	3.09±0.06	3.33±0.02	3.13±0.02	3.24±0.07	3.35±0.02	3.27±0.04	3.30±0.03	3.37±0.06	3.22±0.02
Min. width of pronotum	2.21±0.05	1.90±0.02	2.23±0.04	2.23±0.02	1.92±0.01	2.14±0.05	2.24±0.03	2.11±0.24	2.26±0.01	2.34±0.02	2.11±0.02
Max. width of pronotum	2.51±0.04	2.47±0.01	2.57±0.04	2.56±0.01	2.47±0.01	2.49±0.03	2.55±0.01	2.62±0.02	2.49±0.02	2.60±0.03	2.52±0.01
Length of pronotum	4.99±0.12	4.54±0.09	4.86±0.07	4.98±0.02	4.50±0.09	4.95±0.11	5.04±0.02	5.20±0.02	5.05±0.04	5.17±0.05	5.22±0.08
Span of body with elytron	41.34±0.70	38.46±0.15	40.69±0.74	40.76±0.17	38.66±0.08	39.74±0.77	40.88±0.19	43.51±0.30	39.38±0.43	40.52±0.71	40.94±0.50
Length of elytron	19.43±0.32	18.02±0.23	19.24±0.34	18.89±0.15	18.11±0.15	18.80±0.30	19.09±0.21	20.63±0.17	18.63±0.38	19.06±0.42	19.38±0.24

Width of elytron	2.67±0.04	2.51±0.03	2.71±0.03	2.76±0.01	2.55±0.01	2.68±0.05	2.77±0.01	2.70±0.03	2.56±0.32	2.63±0.04	2.64±0.05
Length of wing	17.60±0.35	15.83±0.19	17.71±0.31	17.01±0.07	16.25±0.10	17.06±0.33	16.91±0.10	18.79±0.09	17.45±0.25	17.62±0.35	17.61±0.30
Width of wing	7.63±0.15	7.21±0.19	7.27±0.15	7.82±0.2	7.25±0.12	7.56±0.15	7.80±0.02	8.21±0.07	7.76±0.06	7.90±0.09	7.70±0.08
Length of ant. Femur	3.26±0.07	2.99±0.09	3.32±0.05	3.44±0.02	3.12±0.01	3.23±0.05	3.46±0.02	3.43±0.04	3.17±0.02	3.32±0.04	3.32±0.03
Length of middle femur	3.66±0.09	3.50±0.03	3.60±0.04	3.73±0.02	3.58±0.03	3.71±0.08	3.80±0.02	3.87±0.05	3.67±0.05	3.87±0.08	3.91±0.07
Length of hind femur	12.44±0.18	11.58±0.11	12.35±0.10	12.79±0.13	11.64±0.10	12.28±0.16	13.08±0.18	13.10±0.12	11.72±0.11	12.29±0.10	12.07±0.14
Width of hind femur	2.37±0.03	2.19±0.03	2.29±0.01	2.40±0.02	2.25±0.01	2.37±0.04	2.43±0.02	2.42±0.02	2.31±0.03	2.35±0.04	2.41±0.03
Width of vertex between eyes	1.01±0.01	0.99±0.01	0.98±0.01	1.06±0.01	0.98±0.01	1.00±0.01	1.05±0.01	1.03±0.01	1.06±0.01	1.11±0.01	1.13±0.01
Vertical diameter of eye	1.80±0.02	1.73±0.01	1.77±0.01	1.71±0.01	1.77±0.01	1.80±0.03	1.77±0.01	1.84±0.01	1.77±0.01	1.85±0.02	1.86±0.01
Horizontal diameter of eye	1.27±0.01	1.23±0.01	1.27±0.01	1.23±0.01	1.23±0.01	1.26±0.01	1.24±0.01	1.31±0.01	1.28±0.01	1.32±0.02	1.36±0.01
Width of head	2.73±0.05	2.58±0.02	2.72±0.02	2.62±0.03	2.59±0.01	2.65±0.03	2.65±0.02	2.95±0.04	2.67±0.01	2.72±0.03	2.68±0.02
Length of antenna	8.41±0.18	8.00±0.16	8.69±0.09	8.40±0.07	8.22±0.13	8.67±0.12	8.48±0.03	9.13±0.13	8.40±0.09	8.62±0.11	8.41±0.17

Table: 51. Effect of food plants on the dimensions of body of *Phlaeoba infumata* Brunn. reared under crowded condition

Female

Indices	Name of food plants										
	Cynodon dactylon	*Paspalum distichum*	*Sorghum vulgare*	*Saccharum officinarum*	*Setaria verticillata*	*Setaria glauca*	*Panicum psilopodium*	*Cyperus rotundus*	*Lactuca sativa*	*Brassica compestris*	*Brassica oleracea or botrytis*
Length of body	29.64±0.33	27.80±0.30	29.08±0.26	27.95±0.40	28.20±0.26	29.74±0.39	28.40±0.49	30.08±0.41	28.82±0.25	30.25±0.39	26.07±0.18
Width of body	5.33±0.13	4.90±0.02	5.43±0.02	4.84±0.06	4.92±0.05	5.39±0.10	5.11±0.08	5.66±0.12	4.91±0.03	5.08±0.04	4.69±0.04
Length of Pronotum	5.20±0.12	5.26±0.04	5.42±0.06	4.88±0.04	5.27±0.05	5.42±0.09	4.97±0.07	5.28±0.01	5.13±0.03	5.21±0.06	5.52±0.03
Height of pronotum	4.49±0.07	4.34±0.03	4.61±0.04	4.12±0.03	4.31±0.04	4.49±0.06	4.19±0.04	4.58±0.08	3.85±0.02	3.92±0.02	4.70±0.04
Min. width of pronotum	3.25±0.06	3.09±0.02	3.41±0.01	2.82±0.03	3.14±0.02	3.16±0.03	3.07±0.05	3.35±0.04	3.00±0.02	3.08±0.03	3.16±0.03
Max. width of pronotum	3.59±0.03	3.36±0.01	3.54±0.02	3.19±0.04	3.44±0.02	3.45±0.33	3.33±0.02	3.62±0.06	3.17±0.02	3.28±0.01	3.44±0.05
Length of pronotum	7.03±0.14	6.48±0.02	6.91±0.03	6.79±0.06	6.55±0.03	7.23±0.13	6.80±0.04	7.14±0.16	6.51±0.05	6.90±0.06	7.05±0.09
Span of body with elytron	53.54±0.91	52.10±0.40	52.97±0.45	52.95±0.41	52.43±0.46	54.34±0.90	53.74±0.43	53.77±0.65	48.80±0.20	50.15±0.32	49.15±0.22
Length of elytron	25.10±0.54	24.70±0.16	24.60±0.15	24.45±0.19	24.88±0.22	25.49±0.32	24.76±0.27	25.30±0.34	22.71±0.16	23.22±0.26	24.58±0.26

Width of elytron	3.55±0.10	3.63±0.04	3.54±0.02	3.54±0.01	3.63±0.03	3.77±0.05	3.55±0.01	3.66±0.09	3.52±0.01	3.58±0.01	3.34±0.05
Length of wing	23.07±0.48	21.78±0.21	22.69±0.09	22.53±0.24	21.70±0.19	22.92±0.32	22.40±0.19	23.24±0.34	21.45±0.14	21.69±0.18	21.08±0.25
Width of wing	10.27±0.23	9.68±0.12	9.97±0.06	9.37±0.12	9.74±0.10	10.43±0.16	9.57±0.12	10.41±0.27	9.45±0.01	9.51±0.01	9.60±0.08
Length of ant. femur	4.29±0.08	4.07±0.13	4.21±0.02	4.13±0.02	4.11±0.02	4.25±0.04	4.14±0.03	4.31±0.06	4.18±0.02	4.26±0.02	4.34±0.05
Length of middle femur	4.94±0.14	4.81±0.05	4.71±0.04	4.58±0.04	4.88±0.03	5.03±0.06	4.72±0.06	4.86±0.09	4.57±0.01	4.65±0.03	5.09±0.02
Length of hind femur	16.64±0.32	16.60±0.16	15.96±0.14	15.36±0.18	16.60±0.12	17.37±0.25	15.95±0.10	16.93±0.27	15.53±0.16	16.11±0.19	15.43±0.17
Width of hind femur	3.10±0.07	3.06±0.01	3.01±0.03	2.92±0.03	3.06±0.01	3.09±0.02	3.04±0.03	3.10±0.02	2.62±0.03	2.77±0.05	2.81±0.04
Width of vertex between eyes	1.45±0.02	1.37±0.01	1.33±0.01	1.34±0.01	1.36±0.01	1.40±0.01	1.38±0.02	1.42±0.01	1.25±0.01	1.39±0.07	1.49±0.03
Vertical diameter of eye	2.17±0.03	2.15±0.01	2.27±0.02	2.08±0.02	2.14±0.01	2.18±0.01	2.11±0.02	2.27±0.01	2.04±0.01	2.10±0.02	2.36±0.03
Horizontal diameter of eye	1.54±0.02	1.56±0.01	1.63±0.01	1.46±0.01	1.58±0.01	1.58±0.01	1.49±0.01	1.57±0.01	1.52±0.01	1.56±0.01	1.51±0.01
Width of head	3.97±0.05	3.77±0.01	3.95±0.03	3.70±0.02	3.81±0.03	3.97±0.05	3.74±0.03	3.99±0.04	3.54±0.01	3.60±0.01	3.80±0.01
Length of antenna	8.12±0.24	8.04±0.08	8.16±0.08	8.07±0.18	8.17±0.16	8.91±0.18	8.44±0.18	8.46±0.15	7.51±0.07	7.72±0.09	9.65±0.09

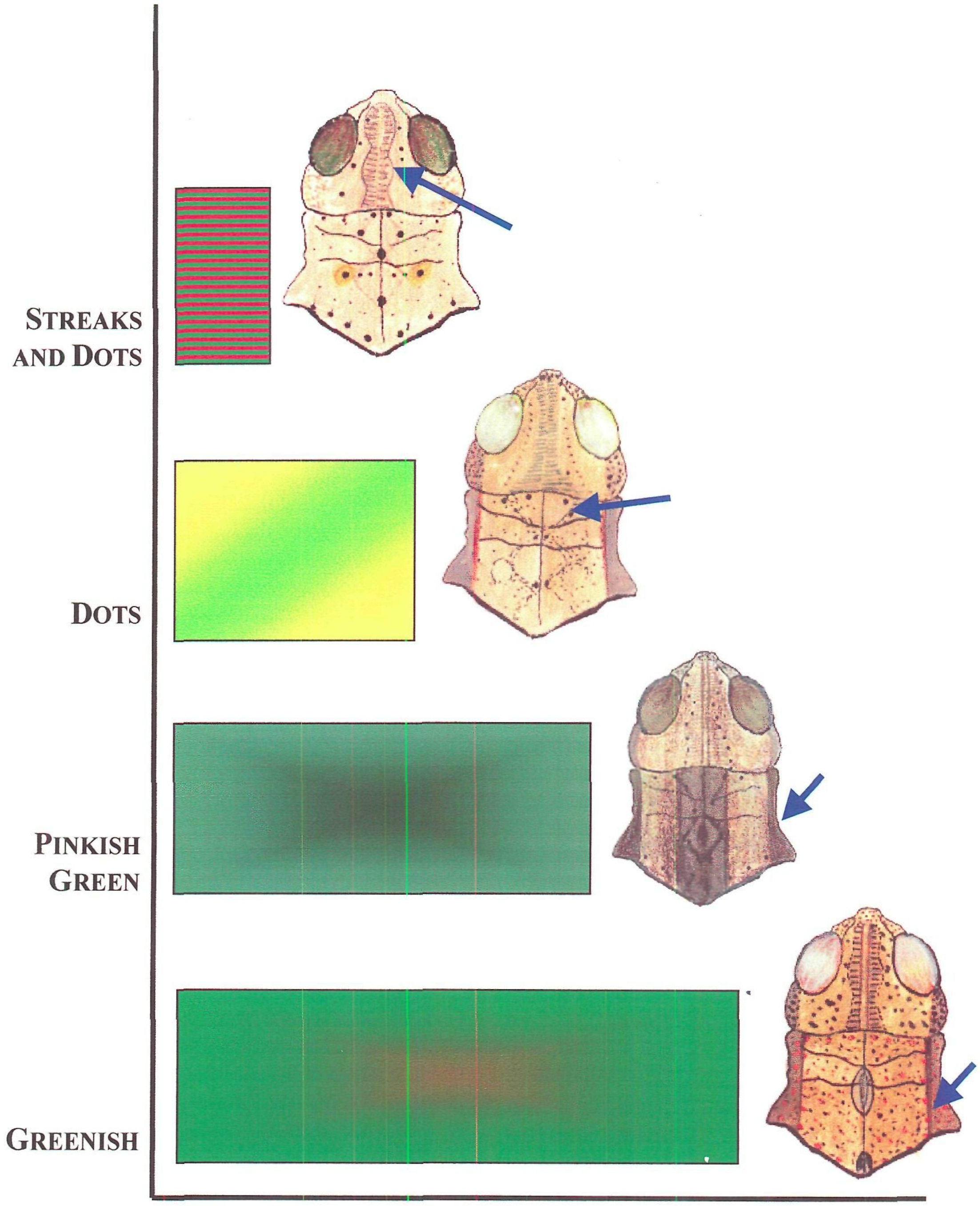


Fig.88. ***Phlaeoba infumata*** **Brunner: Colour dominance during polychromatism at 35±1 °C**

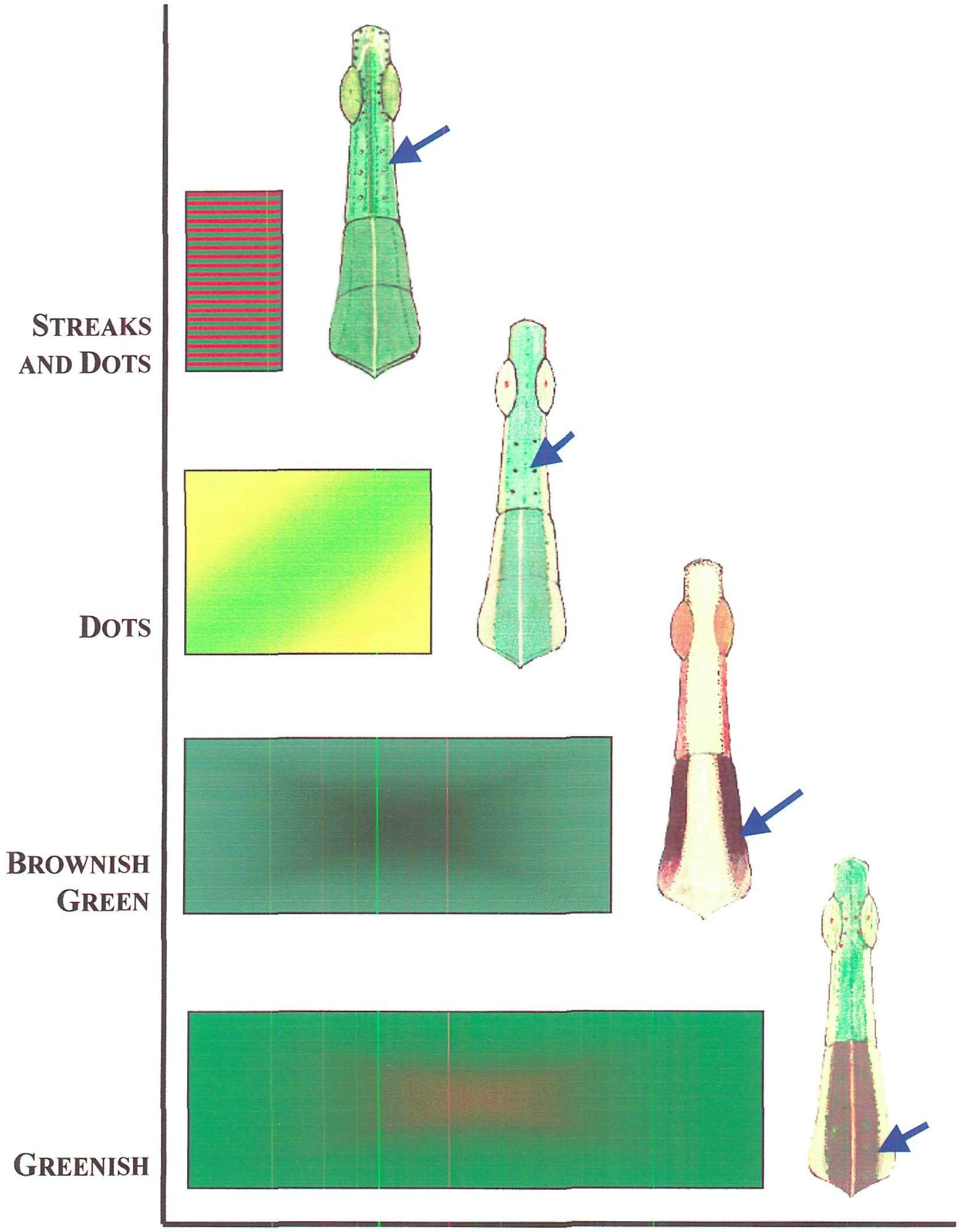
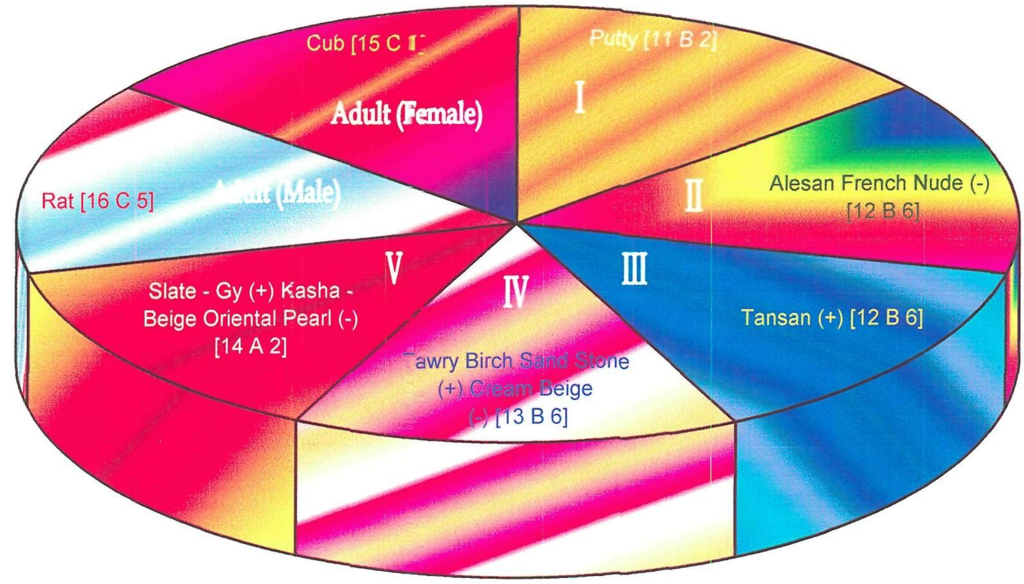
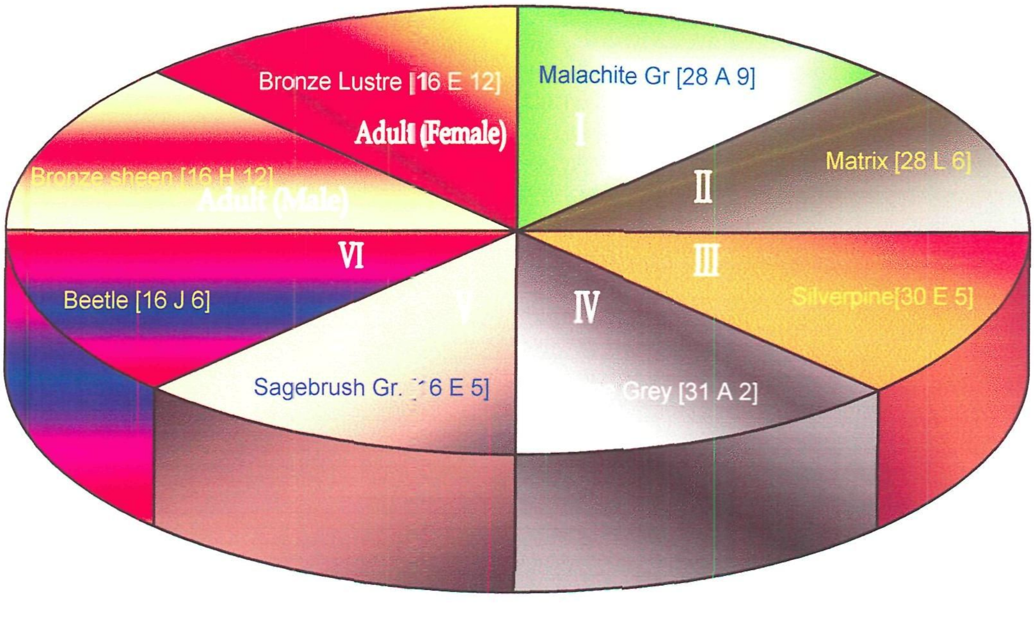


Fig.87.*Acrida exaltata* Walker: Colour dominance during polychromatism at 35±1 °C



A



B

Fig. 86. Pie diagram representing colour dominance agewise in :

A – *Phlaeoba infumata* Brunner

B – *Acrida exaltata* Walker

Name of the Species: ***Phlaeoba infumata*** **Brunnner**
(Orthoptera: Acrididae)

Original Colour: *REDDISH OR OLIVE BROWN OR BOTH COLORS EXHIBIT IN A SINGLE INDIVIDUAL*

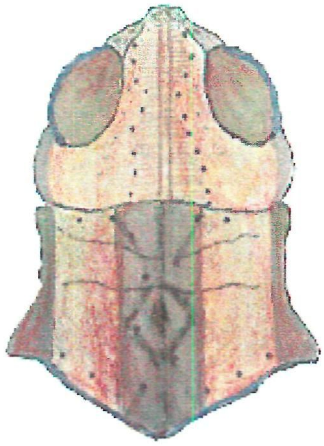
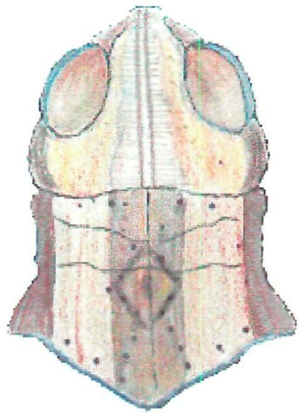
AGE OF INSTAR	COLOR SPECTRA APPEAR UPON PRONOTUM UNDER CROWDED CONDITION	
Adult (Male)		**RAT (16 C 5)**
Adult (Female)		**CUB (15 C 1)**

Fig. 85. Colour Spectra under Isolated Condition [(C) –Male and Female Adults]

Name of the Species: ***Phlaeoba infumata*** **Brunnner**
(Orthoptera: Acrididae)

Original Colour: *REDDISH OR OLIVE BROWN OR BOTH COLORS EXHIBIT IN A SINGLE INDIVIDUAL*

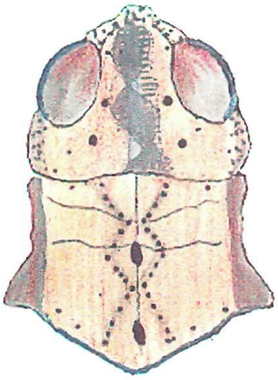
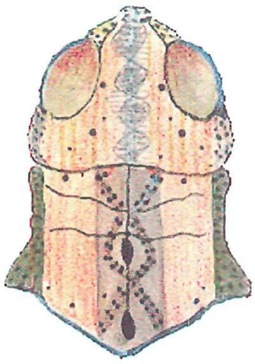
AGE OF INSTAR	COLOR SPECTRA APPEAR UPON PRONOTUM UNDER CROWDED CONDITION	
IV		TAWRY BIRCH SAND STONE (+) CREAM BEIGE (–) (13 A 6)
V		SLATE – GY (+) KASHA – BEIGE ORIENTAL PEARL (–) (14 A 2)

Fig. 85. Colour Spectra under Isolated Condition [(B) – IV and V Instars]

Name of the Species: ***Phlaeoba infumata*** **Brunnner**
(Orthoptera: Acrididae)

Original Colour: *REDDISH OR OLIVE BROWN OR BOTH COLORS EXHIBIT IN A SINGLE INDIVIDUAL*

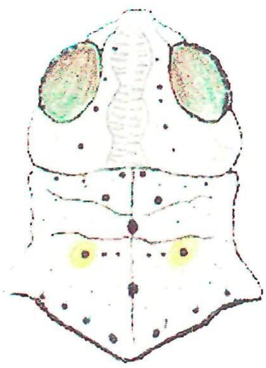
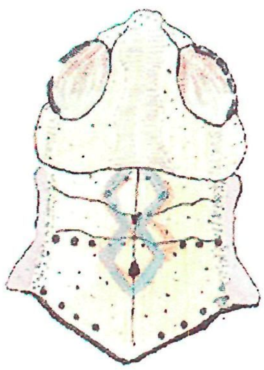
AGE OF INSTAR	COLOR SPECTRA APPEAR UPON PRONOTUM UNDER CROWDED CONDITION	
I		PUTTY (11 B 2)
II		ALESAN FRENCH NUDE (–) (12 A 6)
III		TANSAN (+) (12 B 6)

Fig. 85. Colour Spectra under Isolated Condition [(A) – I, II and III Instars]

REF: **Maerz, A. and Paul, M.R. 1950.** A Dictionary of Color. ***M.B. Inc.*** London. pp.207.

Name of the Species: ***Acrida exaltata*** **Walker**
(Orthoptera: Acrididae)

Original Colour: *UNIFORMLY GREEN, SHADES OF BROWN COLOR WITH PALE MARGINS*

AGE OF INSTAR	COLOR SPECTRA APPEAR UPON PRONOTUM UNDER CROWDED CONDITION	
Adult (Male)		**BRONZESHEEN (16 H 12)**
Adult (Female)		**BRONZE LUSTRE[T] (16 E 12)**

Fig. 84. Colour Spectra under Isolated Condition [(C) –Male and Female Adults]

Name of the Species: ***Acrida exaltata*** **Walker**
(Orthoptera: Acrididae)

Original Colour: *UNIFORMLY GREEN, SHADES OF BROWN COLOR WITH PALE MARGINS*

AGE OF INSTAR	COLOR SPECTRA APPEAR UPON PRONOTUM UNDER CROWDED CONDITION	
IV		**STONE GREY (31 A 2) brown margin**
V		**SAGEBRUSH GR. (16 E 5) median slate stripe**
VI		**BEETLE (16 J 6) dark median slate**

Fig. 84. Colour Spectra under Isolated Condition [(B) – IV, V and VI Instars]

Name of the Species: ***Acrida exaltata*** **Walker**
(Orthoptera: Acrididae)

Original Colour: *UNIFORMLY GREEN, SHADES OF BROWN COLOR WITH PALE MARGINS*

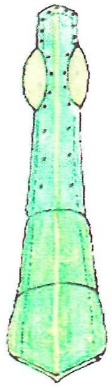
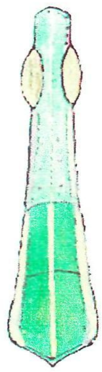
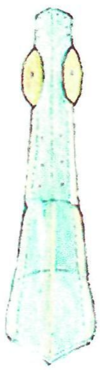
AGE OF INSTAR	COLOR SPECTRA APPEAR UPON PRONOTUM UNDER CROWDED CONDITION	
I		MALACHITE GR^{P} (28 A 9)
II		MATRIX (28 L 6) median slate stripe
III		SILVERPINE (30 E 5)

Fig. 84. Colour Spectra under Isolated Condition [(A) – I, II and III Instars]

REF: Maerz, A. and Paul, M.R. 1950. A Dictionary of Color. ***M.B. Inc.*** London. pp.207.

colours, Malachite GR ^{P}, Matrix, Silverpine, Stone Grey, Sagebrush Gr., Beetle, Bronzesheen and Bronze lustre were shown by *Acrida exaltata* while Putty, Alesan French, Tansan (+), Tawry Birch Sand Stone, Slate–GY, Rat and Cub by *Phlaeoba infumata* respectively. All these colours were found reversible when crowded condition was converted into solitary one. In another preliminary experiment using high temperature (35±1°C) to observed its effects on chromatism and respective colour dominance (Fig. 87). It was amazingly found to be true to our expectations under chromatic concept. In *Acrida exaltata*, the streaks and dots on pronotum were pronounced in early hoppers and dots were more exponentially dark and brownish green in later stages. Similar colour depiction was with *Phlaeoba infumata* and in both the cases, such colour appearances were reversible to original colours when temperature was lowered to 30 ±1°C (Fig. 88). These are the first observations of its kind and that too in a solitary acridid species, having suspected gregarious behaviour. The colour plates are self–explanatory. The observations are very new to literature and to the subject supporting the concept of chromoecology of either environmental factors or gregarizaton phenomenon as envisaged by established locust species of the world. Since these observations are miscellaneous and being reported for future researches separately under the title of chromoecological studies. Such colour polymorphism has been reported by Badruddin *et al.*, (2003) and

Khan *et al.* (2003) in *Choroedocus illustris* and *Oedaleus abruptus* respectively in the occasionally gregarious species. Khan *et al.* (2003) have been able to describe the colour changes as a behavioural indicator of biotic diversity. Present author is of the opinion that the concept of chromoecology as bioindicator of environment and ethological changes proposed by Rizvi (1985) may be considered as an existing biological reality in the Acridid ecology.

DISCUSSION

CHAPTER - VI

DISCUSSION

The adults of *Acrida exaltata* inhabit grasslands but it times becomes serious pest of cotton in north India. They remain solitary but sometimes become gregarious and able to make swarmlets (Rizvi, 1985). Tinkham (1935b) and Hafez and Ibrahim (1958) have recorded its limited range of food plants. The present observations show that it has considerable large range of food plants.

The adults of *Phlaeoba infumata* infest long grasses and even small cultivation fields. It attacks rice fields and nursery plantations of forest seedlings. It becomes pest mostly in monsoon season and severely damages *Kharif* crops in northern India. Adults were found congregating in bushes. Tinkham (1935b) has observed the populations in short and long grasses vegetations. The present observations have revealed a big range of food plants and from vegetables to cereal crops have been damaged severely.

Very little was known about these two species of great economic and agricultural importance and the present observations will complete the biological information about them to make an ecological profile needed.

The act of copulation in these two species has been preceded by elaborate courtship which is of immense interest with reference to the time of copulation lasting about 71.00±8.06 minutes in *Acrida exaltata* and 78.00±5.69 minutes in *Phlaeoba infumata*. The data is variable which can be attributed to the number of attempts successful and low temperature of the night. Similar observations have been recorded by Srivastava (1957) in *Atractomorpha crenulata*; Gregory (1961) in *Locusta migratoria migratorioides*; Hafez and Ibrahim (1958) in *Acrida pellucida* and Basit (1990) in *Gastrimargus africanus* and *Oedaleus abruptus*.

The mechanism involved in oviposition was found to be a typical acridian pattern such as digging, making false holes and showing selection preferences to soil texture. The average egg–laying process was 112.00±12.18 minutes while minimum was 55 minutes and maximum was 180 minutes in *Acrida exaltata* and average egg–laying time for *Phlaeoba infumata*.was 108.50±6.75 minutes while the minimum was 75 minutes and maximum was 135 minutes. The time of egg–laying was also variable during rainfall. Similar observations by Iqbal and Aziz (1974), Basit (1990) in *Eyprepocnemis alacris* and

Oedaleus abruptus, respectively are in agreement with the present author.

The size of the egg-pod is mainly determined by the number of eggs per female. In *Acrida exaltata* the average number of egg-pods per female was found to be 3.68± 0.001 (Isolated condition) and 3.12± 0.12 (Crowded condition) and the size of egg-pods laid earlier was longer than laid later. In *Phlaeoba infumata*, the average number of egg-pods per female was 3.28± 0.01(Isolated condition) and 3.00± 0.13 (Crowded condition). The observations clearly reveal that the number of egg-pods and with their size can provide the total number of eggs expected by the species. Observations made by Majeed (1978) in *G. transversus* and by Basit (1990) in *Oedaleus abruptus* and *G. africanus* are on the same contention and agreement.

The present observations reveal that the isolated and crowded conditions affect the average fecundity of female of *Acrida exaltata* and *Phlaeoba infumata*. Similar observations have been made by Norris (1950, 1952) in *Locusta* and in *Schistocerca*, Albrecht (1959) in *Nomadacris* and Basit (1990) in *G. africanus* and *Oedaleus abruptus*. The behaviour can be attributed to a polymorphic behavioural pattern and appear to be significant in such species which are said to be occasionally gregarious.

Average number of egg per egg–pods was found to be 25.09±0.96 in *Acrida exaltata* and 19.65±0.98 in *Phlaeoba infumata* under isolated condition. Khan (1974) recorded similar observations in *Oedaleus abruptus* while Basit (1990) recorded more eggs in an egg–pod in the same species. Majeed (1978) recorded a range of eggs per pod without mentioning reason. Variation in size of egg–pods obviously can be attributed to the number of eggs per pod and the variations were recorded in *Acrida exaltata* and *Phlaeoba infumata* also. Norris (1950) and Ewer (1977) have recorded gradual decrease in size of the egg–pods, if laid many times by a single female in *Schistocerca gregaria* and *Locusta migratoria* respectively and these observations are in agreement with the present author in *Acrida exaltata* and *Phlaeoba infumata* fundamentally.

The incubation period and hatching time in acridoids in general are recorded by Bernays (1971b) for *Schistocerca* are of great significance. The temperature, moisture and food have been reported to play an important role in successful hatching. Number of observations made by Basit (1990) and by the present author in acridoids shows similar phenomenon and going accordingly.

Attempts made by Ackonor (1988) regarding effects of soil moisture and temperature on hatchling weight and survival in *Locusta* *migratoria migratorioides* is of significance and Amatobi (1996) on egg development and nymphal emergence of *Kraussaria angulifera* in relation to rainfall has been supportive to the ecological behaviour shown by these two species, *Acrida exaltata* and *Phlaeoba infumata* under study with the same ecological niches. This finding made by Gapparov and Latchinisky (2000) regarding consequence of ecosystem on acridid diversity and abundance also support fully the present findings.

Diapause does not occur at any stage of the life cycles of *Acrida exaltata* and *Phlaeoba infumata.* It is possible to obtain 4–5 generations in a year in laboratory as well as in the field conditions. The egg diapause has been recorded in *Gastrimargus africanus* by Golding (1948) but species like *Oedaleus abruptus* and *Gastrimargus africanus* found with *Acrida exaltata* and *Phlaeoba infumata* have not shown any diapause phenomenon (Basit, 1990) and the observations on diapause of *Locusta migratoria cinerascens* suggest that the photoperiod may cause diapause in non–diapausing species but it has not been observed in present speciesunder study. Similar observations were made by Basit (1990) in *Oedaleus abruptus* and *Gastrimargus africanus.* The present author could not find diapause at any stage of life cycle with a long dry season in Aligarh in case of these two species. This observation may suggest that the causes of diapause be initiated with multiple combinations of ecological gadgets.

The development of hoppers is of great interest and many acridologists have reported variations in the number of hopper instars from 4–6 in males and 5–7 in females. In *Acrida exaltata* and *Phlaeoba infumata* there is slight variations in hopper instar numbers such as 6 in males and 8 in females and 5 in males and 7 in females, respectively but on an average and mostly in both cases the life cycle consists of nymphal instars.

Basit (1990) has reported similar biological profile of nymphal instars in *G. africanus* and *O. abruptus*, the species found in the same pattern of niches with the species under study. The number of hopper instars and their variations between species have tabulated in Table 75 as a ready reference in Uvarov (1966), Vol. 1, p. 286 and have attributed to the food of grasshopper but present author does not agree to it as the present two species have not shown any impact of quality and quantity of food on nymphal instars but do effect the nymphal duration in *Acrida exaltata* and *Phlaeoba infumata*. Recently Rizvi *et al.* (2003) have reported nymphal duration under crowded and isolated conditions in *Acrida exaltata*. Earlier similar behaviour was reported by Rizvi et al., (1975) in *Hieroglyphus nigrorepletus*. It means that many factors may affect nymphal duration and instar numbers instead of food alone.

Roonwal's (1952b) statement that most species pass through 5–instars was based on very incomplete data. A number of acridid families are either absent from the table or are represented by few incomplete records and only occasional data are available for tropical species. All contentions regarding nymphal instars cannot be accepted till 2002 but in 2003, the field and laboratory experience of 20 years (Rizvi, 1985) suggests that the number of nymphal instars in acridoids may be attributed to the combination of abiotic and biotic environments well as pressure by the biological control agents from time to time. The present author agrees with Basit (1990) reporting that the trends towards reduction in number of instars in acridids may be attached to the size of the species.

A variation in colour and its pattern has also been recorded from instar to instar up to an adult stage. Observations made by Hunter–Jones and Ward (1959), Rowell (1970), Richard & Waloff (1954), Basit (1990) in *Gastrimargus africanus*, in various British grasshoppers and *Oedaleus abruptus* respectively are of immense value in acridid ecology. Rowell (1970) suggested that the environment determines the colouration in *Gastrimargus africanus*. Rizvi (1985) had created a concept of chromoecology as a visual gadget in phase polymorphism in acridoids. The present author has confirmed the concept through experiment through on *Acrida exaltata* and *Phlaeoba infumata* and other's findings Badruddin *et al.*, (2003) and Khan *et al.*, (2003) have also supported the Rizvi's concept and such chromatic changes are presented as bioindicators of the environmental and biological (crowding) changes. Some useful observations made by Guerruci and Viosin (1988) on the influence of environmental factors on the colour morphs, by Sobolev (1990) on the cryptic behaviour of locusts, by Garlinge *et al.*, (1991) on sex-related morphs frequencies in *Acrida conica*, by Islam *et al.*, (1994) on parental effects on the colouration, by Suresh and Muralirangan (1995) a colour morphs of *Acrida exaltata* in the agroecosystem of Tamil Nadu, by Briddle *et al.*, (2001) speciation in grasshoppers with colour pattern and by Schmidt and Albutz (2002) on sex-linked colouration in desert locust have contributed in establishing a new aspect of acridid ecology based on chromatic changes under certain influences and simultaneously may be used as bioindicators accordingly.

Dyar's law (1890) has been successfully applied to hopper instars of *Acrida exaltata* and *Phlaeoba infumata* as applied by Basit (1990) in *G. africanus* and *O. abruptus*. However no other reference on Dyar's law in acridoids is available. Majeed (1978) has applied the law in *G. transversus* but the number of observations are not convincing.

The eggs of *Acrida exaltata* and *Phlaeoba infumata* are laid in moist soil and hatching was influenced by temperature and humidity gradients. Incubation period was reduced with the lowering of temperature and humidity and vice- versa. Viability of eggs, successful percentage of hatching and survivability was found directly proportional to the optimum temperature, relative humidity gradient accordingly.

Grewal and Atwal (1968) in *Chrotogonus trachypterus*, Iqbal and Aziz (1973) in *Spathosternum prasiniferum*, Basit (1990) in *G. africanus* and *Phlaeoba infumata* have reported similar observations accordingly with reference to environmental factors. A convincing contention made by Montealegre *et al.*, (1998) is in agreement with the present author.

Temperature and relative humidity have been found affecting the hopper duration and developmental index as recorded by the present author in *Acrida exaltata* and *Phlaeoba infumata*. Basit (1990) has concluded with the same contention and results while working on *O. abruptus* and *G. africanus*. Similar attribute has been observed by Pradhan and Peswani (1961) in *Hieroglyphus nigrorepletus*, Parihar (1971) in *Poekilocerus pictus*, Iqbal & Aziz (1973) in *Spathostenum prasiniferum*. Basit (1990) has reported that 35°C was also favourable for the development of hoppers of *G. africanus* and *O. abruptus* and the present author find similar reaction in *Acrida exaltata* and *Phlaeoba infumata*.

Thus on the basis of the present observations, it may conveniently be suggested that increase in the developmental indices at the increasing temperature and relative humidity is due to rapid consumption of more food material.

The life cycles of *Acrida exaltata* and *Phlaeoba infumata* are quite similar in biological profile except insignificant delay of moulting behaviour in *Acrida exaltata* as compared to *Phlaeoba infumata*. Both species have two complete generations in a year and one is overlapping. The first hatching determines the continuance in the development of various stages and the rate of development. Those acridids, which are found in temperate climate with cold winters as found in Aligarh, may be consider as diapause inclined species. Variations in periods and time may be attributed to abiotic regimes experienced by all stages of life cycle. Similar observations by Descamps (1953); Katiyar (1960); Chapman (1961b); Uvarov (1966); Rizvi (1985); Lecoq (1991); Marta Cigliano (2000) are in agreement with the present author in contention and observations as well.

Seasonal variations in the field population of *Acrida exaltata* and *Phlaeoba infumata* in different months of the year 2001, 2002 and 2003 have been recorded by the present author. On similar pattern, the observations on European grasshoppers, Italian locusts, red locusts and desert locust have been recorded by Lensink (1963), Adamovic (1959), Richards & Waloff (1954), Uvarov (1966) accordingly.

Adults of these two species are well adapted to all existing ecological changes and were recorded even in December & January but without reproductive activity.

The population studies of *Acrida exaltata* and *Phlaeoba infumata* with reference to seasonal variations are based on numerical counting of all stages through random catches and their small scale movements. Seasonal variations in north India are of special importance because of open Savanna in Aligarh. The present observations are on the similar pattern used excellently by Richards and Waloff (1954) in British grasshopper. It is imperative to have preferential vales of food of habitat as an important factor so much so that the variations in sex populations are also exhibited. The present author agrees with Richards and Waloff (1954) with reference to all parameters used in the study of population dynamics of these two acridids. However, it was not very convincing that predators play a significant role in population fluctuations.

The distribution of acridoids under study may be correlated with the food plants of the area where populations were maintained. Similar correlation has established by Anderson & Wright (1952); and Iqbal & Aziz (1975). Early stages of *Acrida exaltata* and *Phlaeoba infumata* prefers weeds and grasses and invade crop field while entering into advance stages of life cycle, may be attributed to different type of nutritional preference in food plants. This has got support from Basit (1990) who has concluded with the same contention in *G. africanus* and *O. abruptus*.

Food preferences shown by the acridid under study and projectile is in agreement with Basit (1990) while working on *Gastrimargus africanus* and *Oedaleus abruptus* and the basis involved agrees with Livingstone and Pugalenthi (1992) working on nutritional ecology.

The developmental processes were found to b affected by relative humidity as well recorded in the present species and found similar in effect as recorded by Basit (1990) in *Gastrimargus africanus* and *Oedaleus abruptus*.

The most important aspects of the present studies have been morphometry in relation to suspected gregariousness and chromoecology as bioindicator of the environmental as well as behavioural changes. All morphometrical parameters involved in locust phases have enhance to 21 indices and body parts ratios, thus, analysed have been amazingly found significant confirming that the occasional gregarious behaviour of these two species recorded by Rizvi (1985) is confirmed and supported by chromatic changes as shown by locusts explained excellently by Stower (1959) and also some experiments during morphometrics and chromo-ethology, without any skeptical contention, proves that the two species, though, occasionally gregarious, but definitely inclined towards ' locust in making'

The fundamental observations made by Tatsute *et al.*, (2000), Schmidt (2001), Rehman *et al.*, (2002) and Colombo (2003) while working on polymorphism in acridid with reference to morphometrics has been found fully justified and in agreement with the present author.

Chromoecology in preliminary experimental way was studied and thus found very significant by present author and is fully in agreement with Sword & Simpson (2000), Colvin & Cooter (1995), Guerrucci & Voisin (1988), Eterovick *et al.*, (1997), Islam (1998), Konno (1998), Sobolev (1990), Stebaev (1986), Badruddin *et al.*, (2003) and Khan *et* *al.*, (2003) while experimentally working on colours as bioindicators and polychromatic in behaviour.

Occasional gregarization and discontinuous aggregation in *Acrida exaltata* and *Phlaeoba infumata* are of great biological significance. Similar excellent observations have been made by Joyce (1952b), Ghouri & Ahmad (1960), Basit (1990) in *G. africanus* and *O. abruptus* respectively. The differences in size, colours in gregarious and solitary individuals suggest that the species under study have the tendency of unstable gregariousness and may become 'locust in making'

Therefore, present studies though not in totality, may be suggestive that *Acrida exaltata* and *Phlaeoba infumata* have a tendency of gregariousness and phase formation ability and comparable to non–gregarious phase and formation of swarmlet requires more extension in its ethological profile with reference to ecological–cum–behavioural–cum–morphometrical studies on the same locust pattern and certainly will complete the information accordingly asked for.

SUMMARY

CHAPTER - VII

SUMMARY

Adults of *Acrida exaltata* are found in tall grassland and cultivated grounds during rainy season. The acridid migrates from its original habitat to other new habitats. The adults are distinguished from other economic species throughout most of its range by the hind wings developing into yellow tinge 28–37/ 47–59 and distributed throughout India, Pakistan, Bangladesh, S.E. Tibet, Afghanistan, Sri Lanka, Iran, Yemen AR, Nepal. Adults and nymphs are occasionally gregarious and congregate in masses on thick grasses, bushes and tree tops up to the height of 25 feet, photopositive in nature.

Adults of *Phlaeoba infumata* are commonly found in short grasslands and are chiefly graminivorous and distinguished from its smaller size and brown colouration, the hind wings infuscate apically; hind tarsi reddish, 19–25/ 27–38 and distributed in India (Bihar, Orissa, and U.P.), Nepal, Burma, Thailand, Malaysia and China. Adults and nymphs are gregarious and found crowding in bushes and crop fields photopositive and strong flier to long distances.

Copulation in these two species is preceded by elaborate courtship with special reference to long copulating time.

The mechanism involved in oviposition is of acridian pattern. The egg–laying period takes about 112 minutes for *Acrida exaltata* and 108.5 minutes for *Phlaeoba infumata.* The size of the egg–pod is variable in both cases and mainly determined by the number of eggs laid per female. The average number of egg–pods by a single female, on an average, has been 3.68±0.11 (Isolated condition) and 3.12±0.12 (Crowded condition) in *Acrida exaltata* and 3.28±0.01 (Isolated condition) and 3.00±0.13 (Crowded condition) in *Phlaeoba infumata.*

The effect of isolated and crowded conditions on the fecundity of females of these two grasshoppers has revealed that the average fecundity is affected. Isolated condition produces more eggs than crowded conditions. The average number of eggs per pod was 25.09±0.96 (Isolated condition) and 20.40±0.74 (Crowded condition) for *Acrida exaltata* and 19.65±0.98 (Isolated condition) and 17.59±0.94 (Crowded condition) for *Phlaeoba infumata.*

The incubation and hatching follows a typical acridian pattern with a difference of having enclosure of a cuticular membrane around newly hatched nymphs. The viability of egg–pods, eggs and incubation period was found affected by isolated and crowded condition. The crowded condition affects as in locusts and this behaviour is recorded as a new record in these occasionally gregarious species.

Diapause does not occur at any stage of life cycle and therefore, they have shown throughout the year breeding and sustained populations. At least four generations a year with an additional overlapping generation has given special pest status.

The development of hoppers in these two species is of great interest with reference to least variations in number of instar hoppers as 5– 6 instars in males and 6–8 instars in females. The life cycle is completed in 50–80 days (Isolated condition) and 40–65 days (Crowded condition) approximately in males and about 70–110 days (Isolated condition) and 65 – 105 days (Crowded condition) in females in case of *Acrida exaltata* and about 75–135 days and 85–140 days under Isolated condition in males and females respectively, and 60–120 days and 75–130 days under Crowded condition in males and females respectively in *Phlaeoba infumata*.

The hopper duration is attributed to the number of instars in cycle and crowding affects nymphal duration, which is a new record and addition to the knowledge.

Dyar's law has been successfully applied to the hopper instars of *Acrida exaltata* and *Phlaeoba infumata* and they were reared in constant as well as natural conditions. The application of Dyar's law is new to acridological knowledge.

The variation of colours and patterns are much shown by *Acrida exaltata* and less shown by *Phlaeoba infumata*. Preliminary experiments show chromatic changes under crowded and environmental changing conditions and are definitely indicative of the influences therein.

The eggs of these to species are laid in moist soil and incubation, development and fertility is greatly affected by temperature and relative humidity gradients. The lowest percentage of hatching was recorded as 60.83 at 25° C and 70%±5 R.H. in *Acrida exaltata* and as 63.49 at 25°C and 70±5 % R.H. in *Phlaeoba infumata*. The highest percentage of hatching was 76.14 at 35° C and 70±5 % R.H. in *Acrida exaltata* and 86.67% at 35°C at 70±5

%R.H. in *Phlaeoba infumata* respectively. The average incubation was longest at low temperature and shortest at high temperatures.

The combinations of temperature and relative humidity at lower and higher side was most significant in survivability, developmental rate and day–long activities. Extremes of temperature and relative humidity resulted in high mortality at all stages of life cycle. It was found that higher side of temperature coupled with high elative humidity was most preferred by both species in all stages.

Since both these acridids pest form a common population in north Indian grassland and cultivated crops, their life – cycles are of similar nature except flight potential and vigorous activities of hoppers in *Phlaeoba infumata* is the unique feature as compared to *Acrida exaltata* which was found mostly active when remain gregarious otherwise show least activities.

In both species, the generations have an overlapping generation over and above four complete generations in a year.

Seasonal variations govern the population structure in both the species in different moths of the year. Adults of these acridids are seen active in extreme colder months of December and January with reproductive activities and it may be attributed to an ecological adaptive behaviour.

The population size of these grasshoppers with reference to seasonal variations on yearly basis of all stages through random sampling has been estimated. It was found that the populations were very high with reproductive activities during rainy season in August & September and March & April. The population of hoppers and adult was found pronounce where grasses like *Cyperous rotundus*, *Seteria glauca*, *Paspalum distichum*, *Andropogon adoratus*, *Cynodon dactylon* were dominating the vegetation. The fluctuation in numbers of grasshopper is attributed to the other ability of these grasses. The early nymphal instars have preferred *Cynodon dactylon* while the advance stages like to enter in the crop fields.

The small scale movement of all stages of these grasshoppers were extremely influenced by day temperature and relative humidity, air speed, light, and human activity and after sun set they were hidden under thick vegetation.

The food preference in nymphs and adults and successful completion of cycle have been recorded typically in these grasshoppers. It was found that the distribution of these species remains directly proportional to the preferential value of the food plants available.

The most important and needed aspect of this study was the morphometrical analysis and chromatic profile. In both the species, all parameters and body parts and their ratios as done in locusts were tested and thus amazingly majority of them were highly significant leading to a conclusion that the species have tremendous ability to become gregarious when environmental and biotic conditions are available suited to the behavioural profile. Both the species were put to isolated and crowded conditions in order to establish any hidden instinct of being locust 'locust in making' may be researched out. These observations were corroborated with visual, occasional, record on these species. The gregarious behaviour was definitely exhibited but with discontinuous aggregational behaviour. The observation certainly leading to accept the fact that both the species are having distinct behaviour of gregarization, swarm forming and having ability of mass active behaviour with local migratory instincts. These observations are the substantial addition to the knowledge of polymorphism in acridoids.

The chromatic changes, thus, observed visually were tested under experimental designs and amazingly found that the colour spectra shown were on the same pattern as in locust species and were reversible as and when ecological conditions were changed.

On the basis of the present studies it can convincingly be concluded that the species under study are very dangerous in behaviour, can assume new dimensions of behaviour, may become gregarious and migratory under suitable ecological parameters. The life-cycle of these species hitherto unknown, have been made known. A complete ecological profile, under all considerations, has been completed and the entire research work will be in addition to entomologist in general and very special to acridologists the world over.

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A NEW RECORD OF PARASITIC CASTRATION IN THE GRASSHOPPER, *HIEROGLYPHUS NIGROREPLETUS* BY THE ECTOPARASITIC RED MITE, *EUTROMBIDIUM TRIGONUM* (ACARINA : TROMBIDIIDAE)

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The red mite, *Eutrombidium trigonum* Hermann, an acarine ectoparasite of the rice locust, *Hieroglyphus nigrorepletus* Bol., a major pest of rice in north India, has been reported as parasitizing the nymphal as well as adult stages (Peswani, 1960; Rizvi & Aziz, 1974). Its biology has been worked out (Severin, 1944; Rizvi *et al.*, 2003) with an observation of attention that the parasite affects the sexual maturity in both sexes of the host. Keeping this pertinent indication, the present investigations were designed and experimented on the sexual life of the host.

The experiment was done with male hoppers, which were exposed to newly hatched nymphs of the mite preferring earlier hoppers. The observations were made on 10 sets of five male (Ist instar) in a jar (15×10 cm.) providing wheat leaves at a constant humidity (70%) and temperature (32°C ± 2°C). When the grasshopers became adult (after 7 moults, taking 52 days), only 8 adults showed sign of testicular development, while other 42 adults could not develop the testes. This castration led to non-sexual life of the adults under experiment. The efficacy of parasitic impact was found statistically significant ($P<.01$) at 5% level of significance.

The present observations are congruent on the description made by Huffecker & Rabb (1984) that true parasites rarely kill their victim, presumably reduce their vigour. Those parasites that castrate their host are also important by reducing their reproductive potential without killing the host.

The present observation is a new record of significance in grasshopper biology, which could be utilized in containing the male population and indirectly becoming a biocontrol tool in IPM especially for acridoids.

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Herbal Contraceptive Cream

The Central Drug Research Institute, Lucknow, is set to add yet another feather to its cap. It has developed a plant-based spermicidal cream 'Consap', which is likely to hit the market soon. The cream, made from *Sapindus mukrosii* (Reetha), would regulate fertility (it would prevent a woman from conceiving).

The marketing licence for 'Consap' has already been obtained. However, it will take another 5-6 months to get through the final stages and put everything in place for its proper launch.

Sources said that the plant was studied throughly, its extract was taken out and subjected to a wide range of biological activites. In fact, the plant material went through 180 screen systems. When its potentiality was proven, detailed chemical examination was conducted on it.

Already, the CDRI has developed 11 new drugs till date. Four drugs are currently in the market, one nonsteroidal oral contraceptive called 'Centchroman', two antimalarial drugs and one herbal remedy for memory enhancement.

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A NEW RECORD OF CHROMO-ECOLOGICAL STUDIES AS BIO-INDICATORS IN POLYMORPHIC BAMBOO LOCUST, *Choroedocus illustris* (ORTHOPTERA : ACRIDIDAE)

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ABSTRACT

Acridids having single colour pattern, have shown spectra of colour patterns when subjected to various environmental abiotic and biotic parameters that too in solitary one. This is the first record in Acridological studies while studying occasionally gregarious, *Choroedocus illustris*, a serious pest of bamboo plantations. These amazing observations are definitely to be utilized as bio-indicators for changing environmental conditions through colour changes in various biological forms of the acridid under study.

INTRODUCTION

Nothing is known about polymorphic bamboo locust (*Choroedocus illustris*) ALM-14, London) except Hussainy (1951) reported as pest of sugarcane at Coimbatore (S. India). Recently, It has assumed a status of being a serious pest of bamboo in Aligarh (Lat. 27° 34' 30"N, long. 78°4' 26" E). During its ecological studies some amazing ethological observations (Rizvi et al. 2002) have suggested sharp interaction of the species with changing environmental scenario usually presented by spectra of color on thorax, like desert locust that the species may be taken as bio-indicator. The biology of the pest has also shown polymorphism deviated from solitary form. Moreover, polychromatic stages also indicated the biological timings of their gregarization and swarm formation, which were not earlier recorded. Only, such color patterns, Stower (1959) has recorded in *Schistocerca gregaria* without any relevance to environmental changes.

MATERIALS AND METHODS

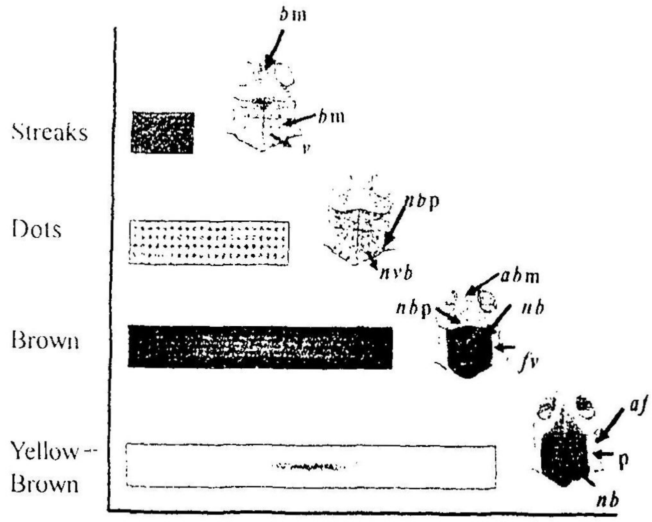
Choroedocus illustris was collected from its breeding places and a life-line was maintained in order to have various stages for experimental purposes. All colour changes were described by using Maerz and Paul (1950), a dictionary of colour. Special cages were designed to rear the insect providing 10 hours light and maintained temperature and humidity in constant temperature room in the department.

RESULT AND DISCUSSION

Results of three parameters were obtained as :

a) **Hopper subjected to 27 ± 2° C**

All six stages have shown light brown colour with yellow lateral lines unchanged (Plate 1).

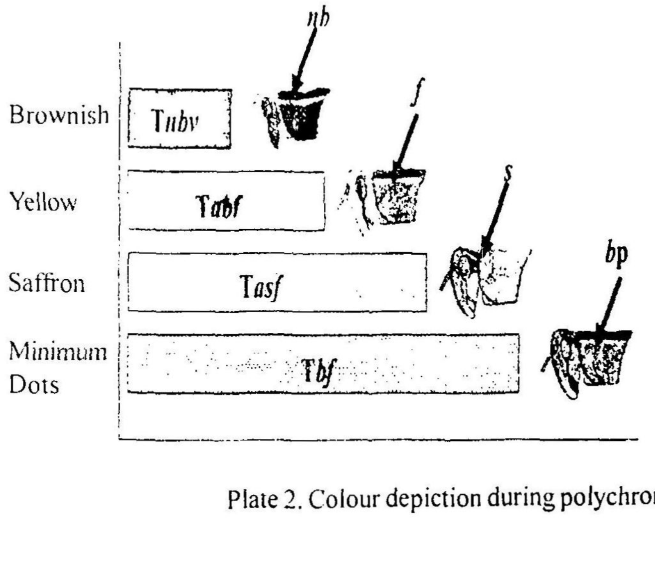


Abbreviations used : Clark's Notation (ALB-17, 1954)
* af = light yellow*
* abm = light brown with coarse spotting or streaks
* bm = brown with coarse spotting or streaks
* bp = brown fine spotting
* fv = yellowhish green coloured
* nb = dark brown coloured
* nbp = darkbrown fine spotting
p = fine spotting
v = green coloured

Plate 1. Colour dominace during polychromatism at 27±2°C

b) Hopper subjected to 35 ± 2° C

All six stages have shown change in light brown colour to dark brown colour and yellow lining becoming lighter and lighter. In late instars (IVth and Vth) black spots appeared and congregations leading to band formation (Plate 2).



Abbreviations used : Clark's Notation (ALB-17, 1954)
* Tabf = light brown dorsally and yellowish laterally
* Tasf = light saffron dorsally and yellow laterally
* Tbf = brown dorsally and yellow laterally
* Tnbv = dark brown dorsally and brownish green laterally
* nb = dark brown coloured
* f = dark brown fine spotting
* s = fine spotting
* bp = green coloured

Plate 2. Colour depiction during polychromatism at 35±2°C

Table 1. Chromatic behaviour of different stages at 27±2°C and 35±2°C

STAGE		CONDITION	
		27±2°C	35±2°C
III INSTAR		14 J 7 (Calabash)	7 J 6 (Garnet)
IV INSTAR		8 H 9 (Chocolate Brown)	47 A 3 (Gris)
V INSTAR		5 L 11 (Brick dust)	1 L 5 (Grayon)
ADULT	Male	16C 9 (Bronze brown)	9 K 2 (Chrome Citro)
	Female	13 D 2 (Bronze Clair)	38 J 12 (Chiswick)

c) Hopper subjected to crowded condition

When 50 hoppers were reared in a jar of 7 × 4" size, have shown tremendous activities with dark colour formations (brown, metallic and red) with black spots and released in a surrounded field, have shown similar behaviour that is exhibited by established locusts like band formation, marching pattern and basking in sun radiations.

When above conditions are altered, that was lowering temperature and making solitary orientation, the original and natural colours and behaviour got reversed, that confirms the locust like behaviour.

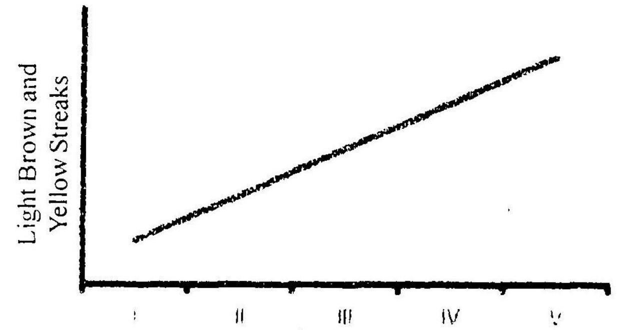


Fig. 1

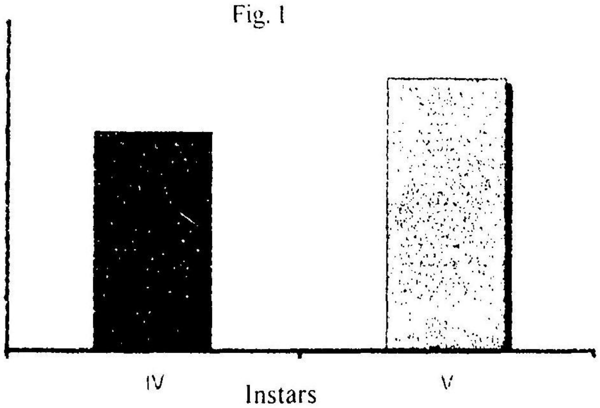


Fig. 2

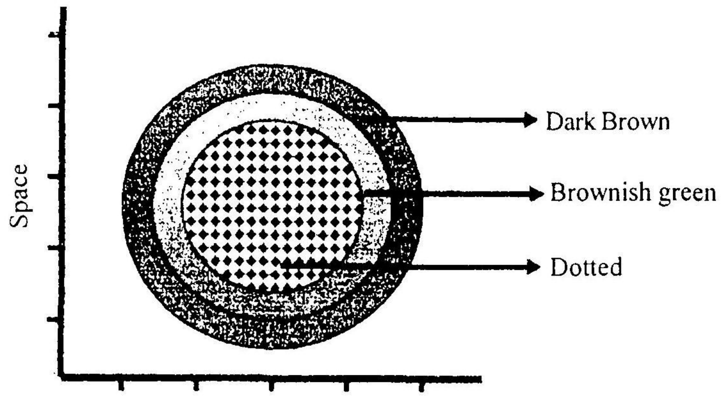


Fig. 3

Stower (1959) studied simply the patterns of colour in hoppers of *Schistocera gregaria* but experimental part was omitted and therefore, significance of chromatic changes and that too, be taken as bio-indicators. Appear to be the original first record, already expected by Rizvi, (1985) in other occasionally acridoids in N. India.

The present observations and results will enhance the concept of chromo-ecology and its application may be of immense use to plant protection people in time to come.

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ENVIROMMENTAL STUDIES ON OCCASIONALLY GREAGARIOUS LESSER MIGRATORY GRASSHOPPER, *OEDALEUS ABRUPTUS* (ORTHOPTERA : ACRIDIDAE)

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ABSTRACT

Oedaleus abruptus, pest of rice, millet, jowar and gram and recently inflicting losses to sal and teak plantations, occasionally gregarizing and presenting chromatic spectra associated with ecological changes as in locusts, attracted present studies on chromo-ecology with special reference to solitary and gregarious forms, amazingly yielded most technical scenario comparable to phase polychromatism in established locusts. Observations will certainly be of great eco-environmental significance pertaining to agro-ecosystem in India.

INTRODUCTION

Short term reversible colour change resulting from the movement of pigments only occurs in few insects and similar studies made by Stower (1959) in *Schistocera gregaria* hoppers in both, solitary and gregarious phase, have given a new concept of chromo-ecology. This has been tested by Rizvi *et al.* (2002) in *Choroedocus illustris* considering crowding conditions as a biotic factor. Phase polymorphism in locusts has generated biological interest of utmost importance to ethologists in general, in which coloration of solitary and adult hoppers is of uniform nature while gregarious locusts have a heavy black pattern typical of their species, on a yellow or orange background. Similar phenomenon was being tested in order to confirm the occasional gregariousness in *Oedaleus abruptus* appear to be instinctive or accidental. *Oedaleus abruptus* is pest of rice, millet, jowar and gram (Basit, 1990) and recently inflicting losses to sal and teak plantations

MATERIALS AND METHODS

New hatched hoppers were reared into category : (a) one hopper/jar (b) 50 hoppers/jar

The jars remained of the same size (7″ × 4) and the temperature (32 ± 2 °C) was constant. Both sets were fed on maize leaves in 70% R.H. On completion of experiments, only III, IV and Vth instars have shown color pattern changes under crowded conditions, which were identified by using dictionary of color by Maerz and Paul (1950), London.

RESULTS AND DISCUSSION

Solitary *Oedaleus abruptus* nymphs remained green, brownish muddy with light pink streaks. But crowded hoppers showed distinctive chromatic changes on locust patterns (Table 1). The IIIrd instar changed into 8H10 (Norfolk) till it moulted to IVth instar and completely changing color from 8H10 to 12L5 (Venus) with vigorous activities. After the IVth moult, they metamorphosed into Vth instar with very different dark pattern, 15C11 (Cocoa Brown) and become more vigorous and jumping and aggregating on twigs. Such chromatic changes speak of their behavioural manifestation in colors very close to locust behaviour. The black color appearance is associated with crowding in locusts.

Table 1. Chromatic behaviour of III, IV and V instars larvae under solitary and gregarious condition.

Stage	Condition	
	Solitary	Gregarious
III instar	55 A2 (Plumbeous)	8 H 10 (Norfolk)
IV instar	45 B 2 (Cloud Grey)	12 L 5 (Venus)
V instar	13 A 2 (Piping Rock)	15 C 11 (Cocoa Brown)

These observations are on similar concept that has been tested by Faure (1932) in *Locustana* and in *Dociostaurus* by Pasquier (1934). Rizvi (1985) has reported that *Oedaleus abruptus* might be 'Locust in Making' on the basis of its morphometrics and color polychromatism and the present observations are in full agreement with reported concept and are of the opinion that if environmental changes exert ecological stress, the grasshopper has definitely a tendency to go to polymorphic morphometrically as well as chromatically. Since chromatic changes were found reversible when crowding was reduced to solitary, all the more confirms the hidden gregarious behaviour earlier reported by Uvarov (1977).

The observations will be of immense value in assessing the expected gregarious behaviour of *Oedaleus abruptus* and will help the plant protection personals to go for a more reliable suggestive control measure for the pest under study.

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RECORD OF AN EARWIG PREDATOR ON THE EGGS OF *TRILOPHIDIA ANNULATA* (ORTHOPTERA : ACRIDIDAE)

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After the collection of acridid eggs by one of us (N.M.) from J.&K. State, when they were left for laboratory hatching, it was found that several eggpods (78 in total) contained earwigs. These were separated and the earwig species was identified as *Diplatys angustatus* Burr (Dermaptera : Forficulidae). On an average 60-70% eggs were found damaged severely. Undamaged eggs were kept separately in an incubator (32 ± 2^{0}C + 70-75% R.H.), which later hatched and were raised upto adult stage. These grasshoppers were identified as *Trilophidia annulata* Thunberg, having brown to dark gray with blackish spots, and measuring 18 mm in size. This species is found in Kashmir and Sikkim as pest of rice, teak and mulberry plantations.

The number of eggpods of this grasshopper pest have shown that the earwigs entered into the eggpods by removing spongy plug and then voraciously fed on eggs. Among the insect predators, the forficulids have, however, not been mentioned as predators of any stage of the locusts (Uvarov, 1977). However, Lal (1945) and Rizvi & Aziz (1966) have reported earwigs attacking acridid eggs at Orai (U.P.) and Aligarh (U.P.), respectively.

The preliminary statistical analysis, based on Mills (1977) hypothesis, the predation efficacy thus calculated, has been found significant at 5% level of significance. It is suggested that the predator be studied for association of earwigs with the Acridids, as it can be of immense value in the biological control of this grasshopper agricultural pest.

Acknowledgement: Thanks are due to Mr. Naseem Ahmad, IAS, Vice-Chancellor, A.M.U. for manifold help.

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Odum, E. 1971. *Fundamentals of Ecology.* W.B. Saunders Co., New York.

Roonwal, M.L. 1982. Fauna of the Great Indian desert. *In : Desert Resources and Technology* (Ed. A. Singh). Scientific Publishers, Jodhpur : 1-86.

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RECORD OF DAMAGE TO SOME MEDICINAL PLANTS BY THE NURSERY LOCUST, *PHLAEOBA INFUMATA* (ORTHOPTERA : ACRIDIDAE)

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The nursery locust, *Phlaeoba infumata* Brunner, has been reported as a major pest of rice, maize and sugarcane (Roffey, 1979). During surveys made in September 2000 in and around Aligarh, the present authors found that some medicinal plants under cultivation in the area were severely damaged at seedling stage inflicting considerable loss. One of the authors (N.M.) made collection and it appears that it is a first report of damage to these plants by this insect.

The plants damaged were – *Abrus precatorius* (Leguminosae), leaves of which are used as stomach tonic, in asthama and piles; *Abutilon hirtum* (Malvaceae), leaves, bark, roots and seeds of which are used in fever and in diuretic medicines; *Acacia pennata* (Leguminosae), leaves of which are used in curing bleeding gums and snake bites; *Acalypha indica* (Euphorbiaceae) which is used in pneumonia, asthama and scabies treatment; and *Achyranthes aspera* (Amaranthaceae) which is used as purgative and diuretic, in dropsy, piles and boils treatment (Chopra *et al.*, 1956).

The study shows that the acridid pest is having devastating effect on these plants which are important biologically as well as ethologically. A single female lays more than 50 eggs, fertility goes upto 80% and it passes through 5 nymphal stages and breeds throughout the year. The insect is found occasionally gregarious and swarm forming.

Assessment of losses to medicinal plants was calculated by method based on amount of plant consumed. It confirmed the efficacy of damage being statistically significant ($P<0.05$) at 5% level of significance. Similar observations were made earlier by Aziz & Rizvi (1967) reporting another grasshopper *Oxya velox* damaging some medicinal plants.

Acknowledgements : Thanks are due to Mr. S.K.A. Rizvi for supervision and to Mr. Naseem Ahmad, IAS, Vice-Chancellor, Aligarh Muslim University, for financial support.

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15 yr–old Girl on Everest

Nepalese Sherpas continued to rewrite climbing history as Everest heroes from across the globe began assembling here for the 50th anniversary of the conquest of the peak by Edmund Hillary and Tenzing Norgay.

Ming Kipa Sherpa, a 15-year-old girl from eastern Nepal's Sankhuwasabha, became the youngest climber ever to scale the 8, 848mt summit.

She, along with sister, Lhakpa (30) and brother, Mingma Gyalu (24) reached the top from the Tibetan side on 24th May, 2003.

Prior to this, Temba Chhiri Sherpa, also from Nepal, had held the record after he set foot on the Everest at the age of 16 in 2001.

Many had expected that Temba's feat would remain unbroken after Nepal banned climbing by under-17s last year. But the three choose to scale the summit from Tibet where there is no such ban. The Nepal Mountaineering Association said it was verifying Ming's age.

This is also the first time that three of a family ascended the earth's highest point at the same time. Besides, Lhakpa, who had ascended the peak in 2000 and 2001, became the first woman to conquer Everest thrice.

Hundreds also welcomed Pemba Dorjee Sherpa (25), who climbed the Everest in a record time of 12 hours 45 minutes as he reached here on Sunday. "Next time, I will make a full round of Everest. I will start from this side and descend from the Tibetan side," said the world's fastest climber.

Pemba has also put the portraits of the Nepalese King, Queen and the Dalai Lama on the peak. He remarked, "I climb because I don't want foreigners to achieve rare feats before us, the Nepalese."

treatment in affording maximum protection to stored rice from insect attack is proved beyond doubt.

Table 1 Cumulative number of rice weevil (S. oryzae) (Linn.) adults in sun-dried rice grains

Sun-drying treatment for (days)	Number of adult weevils emerged after various intervals (days)			
	30	60*	90**	120**
1	0.00 (3.31)	10.00 (5.79)	34.29 (7.87)	62.66
3	0.00 (2.37)	1.67 (4.90)	24.08 (6.48)	42.00
5	0.00 (1.00)	0.00 (3.45)	11.95 (5.24)	27.44
Control	0.00 (3.61)	12.06 (6.20)	38.45 (8.25)	68.20
CD at (0.05)	-	0.41	1.18	0.90

*Figures in parenthesis are $\sqrt{x+1}$ transformed values.

**Figures in parenthesis are $\sqrt{x}$ transformed values.

A New Record of Parasitic Mite, *Podapolipus diander* Volkonksy (Acarina : Tromdidiformes : Podapolipodidae) on *Oxya velox* (Fabricius) (Orthoptera : Acrididae)

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During field studies on the life cycle and ecology of *Oxya velox*, a serious pest of rice in and around Aligarh (lat. 27° 34' 30" N, long. 78° 4'26" E), large numbers of trombid mites of various larval stages on the hoppers and adults were recorded on *O. velox*. This may have potential of being used as biocontrol agent.

The mite was identified as *Podapolipus diander* reported by Volkonksy (1940) parasitizing *Locusta migratoria* in Algeria, showing degenerated forms, remaining more or less in the larval stage. The mite, heavily parasitizing *O. velox*, was found attached under posterior extension of the pronotum, coxal bases, legs, wing pads and maxillae, totalling 30-35 / host in which adult females were less than larval stages.

The spread of parasitic mite may be from grasshopper to grasshopper directly. This is the first report of the mite on *O. velox*.

Reference

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Calobata indica : A New Record on Ginger in Himachal Pradesh

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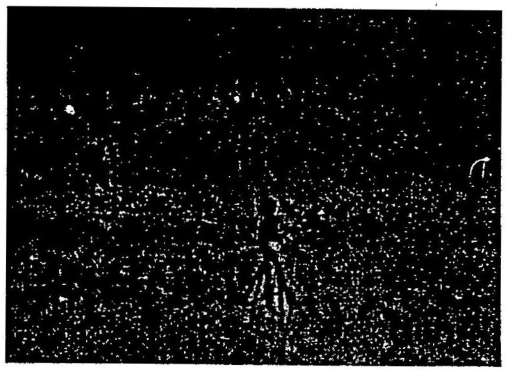
Calobata indica (Diptera: Micropezidae) commonly known as ginger rhizome fly was recorded for the first time damaging ginger rhizomes in Sirmour of Himachal Pradesh (Anonymous, 1996). Earlier, Lefroy (1909) recorded and bred this fly from the decaying roots of ginger plants in West Bengal, Nair (1976) observed feeding by maggots of *Calobata indica* on rhizomes in Kerala.

The fly is black in colour with long legs, a long narrow body and wings. Wings are often marked or spotted with anal cells. Eggs are laid on the pseudostem in July-August, whereas in September, eggs are laid on the freshly formed rhizomes directly hidden below the tiny scales.

Within 24 hours, eggs hatched into tiny legless maggots. Inside the rhizomes they pass through 4 instars and are full grown in 7-8 days. Apparently rhizome seems healthy but after cutting the rhizome, one can see white coloured legless maggots moving inside the rhizome. Pupal stage is inside the rhizome and lasts for 6-8 days.



Studies conducted on the seasonal incidence revealed that maximum population of maggots / rhizome was recorded in September (43.8) followed by October (36.7), November (10.7), August (9.6), December (6.2) and July (6.0). In July, maggots were found in pseudostem only.

EFFECT OF CROWDING ON THE NYMPHAL DURATION OF *ACRIDA EXALTATA* (ORTHOPTERA : ACRIDIDAE)

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Uvarov (1977) has mentioned that the tendency of gregarization in the grasshoppers and locusts can be assessed on the basis of nymphal duration in ecological conditions versus space. Effect of crowding on the nymphal duration of *Hieroglyphus nigrorepletus* Bol. was recorded by Rizvi *et al.* (1975) taking into account the nymphal duration differences in solitary and gregarious phases. There seems to be no other record of such nature in grasshoppers, though many species show occasional gregarization.

Present authors have found that the *Acrida exaltata* Walker species has tendency of occasional gregariousness and shows marked differences in morphometrical as well as chromoecological behaviour. The experiment on crowding effect on nymphal duration was carried out with 50 freshly hatched nymphs, which were reared at 32^{0}C$\pm$2 ^{0}C in glass jars of the same size (15×10 cm.). At the same temperature, 10 hoppers were reared in another glass jar. The former batch of hoppers got less space in terms of per hopper space, as compared to the latter batch of hoppers. Nymphs reared in crowded condition took 35 to 45 days; but those reared under isolated condition took 75 to 80 days, in completing their development. The average nymphal duration under crowded and isolated condition has been recorded as 40.0 and 78.5 days respectively (Table 1). These

Table 1. Effect on nymphal duration of *Acrida exaltata* under crowded and isolated condition.

No. of Hoppers	Stages (Instar/adult) I II III IV V	Adult	Differential finding
50/Jar	35-45 days 7-9 days moulting period	Pinkish Greenish Brown	Become migratory in nature
10/Jar	75-80 days 15-16 days moulting period	Remain green through out	Remain non-migratory

Space : 15×10 cm; Temperature : 32$\pm$2^{0}C; R.H.: 60-65%

observations are in agreement with Rizvi *et al.* (1975) in *Hiroglyphus nigrorepletus,* a pest of rice.

The present observations are indicative of an instinct hidden in *Acrida exaltata* to be a locust in time to come, and it may help acridologists to make further studies on other non–swarming grasshoppers.

Acknowledgements: The authors are thankful to Mr. Naseem Ahmad, IAS, Vice-Chancellor, Aligarh Muslim University, for financial assistance and to Mr. Shafiq Ahmad, F.O., for encouragement.

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Carbon Lies Beneath Earth

German researchers have now confirmed what scientists always feared: that there's an immense cache of carbon just below Earth's crust, that could some day be released into the atmosphere. So what if there's all that black sludge swishing around in the basement, one may be tempted to ask. If and when the planet throws up even a little of that stuff from downstairs, it would be lights out for most of the species now extant.

For such a planetary burp would release vast quantities of carbon dioxide (CO_2) into Earth's protective cocoon, engendering a 'runaway greenhouse effect'. Laden with all that CO_2, the atmosphere would have little choice but to trap sunlight and barbecue plant life which, in turn, would kill off animal species strung along the food chain. Earth's upper mantle is mostly made up of a crystalline silicate called olivine where, it was believed, the carbon was stored. The high melting point of the olivines made them remain relatively stable and retain their carbon deposits even in the furnace-like heat of Earth's core. But the latest research seems to have trashed that theory and identified *carbonates* as the likely place where carbon is stored in Earth's bowels.

Since carbonate rocks have a very low melting point, they survive the fiery heat and squeeze through cracks towards the surface, absorbing more carbon as they go. All it'd then take is a volcanic eruption to lay an impenetrable CO_2 smokescreen for the biosphere, and trigger another round of 'mass extinction', as has happened before on Earth. This must be a sobering thought for those who are currently busy with a global experiment to see how quickly they can double atmospheric CO_2 levels.

Forecast of Rice Leaf Folder, *Cnaphalocrocis medinalis* Guenee. Incidence

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The incidence of rice leaf folder, *Cnaphalocrocis medinalis* Guenee. in relation to the prevailing weather condition has been studied during two kharif seasons of 1999 and 2000. Twenty hills were randomly sampled at weekly intervals during the crop period, on rice cv. *Lalat* between 15th July and 15th August, following agronomic package of practices.

The influence of weather on the incidence of leaf folder was quite evident when these parameters were correlated. Among the factors, the minimum temperature influenced the foliage feeder inversely in 1999 (r=-0.852*) and in 2000 (r=-0.791*) with the average of two years data also showing the same trend (r=-0.819*) (Table-1). Thus, the role of minimum temperature was conspicuous (R^2=62.6-72.6%) in bringing out the fluctuation in the intensity of leaf damage. Relative humidity (RH) and rainfall, was non-significant.

Thus, it is concluded that a fall in the minimum temperature (<20°C) during last week of September and 1st week of October coupled can favour leaf folder infestation in rice crop whether planted early or late.

Table 1 Correlation between weather parameters and the leaf damage by rice leaf folder

Parameters	Correlation coefficient (r) (n=7), during			Coefficient of determination (R^2 in %), during		
	1999	2000	Mean	1999	2000	Mean
Leaf damage Vs. Max. tempt.	+0.142	+0.363	+0.183	2.0	13.2	3.3
Vs. Min. tempt.	-0.852 *	-0.791 *	-0.819 *	72.6	62.6	67.1
Vs. RH	-0.482	-0.621	-0.663	23.2	38.6	44.0
Vs. Rainfall	-0.124	-0.466	-0.213	1.5	21.7	4.5

*Significant at 5% level.

Record of the Predator *Erythracarus* Berlese (Acarina: Anystidae) on *Oxya velox* (Orthoptera : Acrididae)

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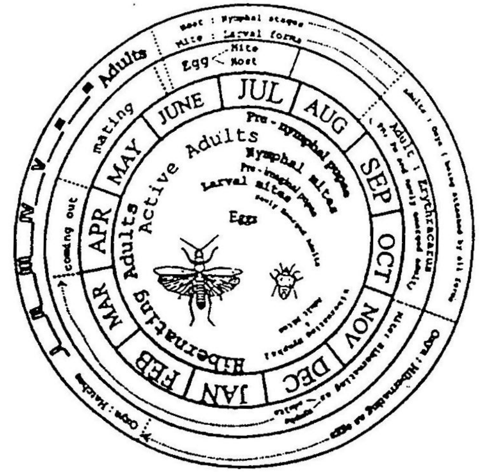
Long legged fast moving mites, *Erythracarus* Berlese (Oudemans, 1936), is being reported for the first time as predaceous on *Oxya velox* (Fabricius), a major pest of Orthopteroid pest of rice in north India. A study on occurrence, its biology and host-predator relationship was made at Aligarh and thus found most voracious predator on hoppers and adults and also on eggs of the grasshopper. A compact diagrammatic presentation on synchronization of biology of prey and predator is given below. The mite may be useful as a biological control agent against acridoid pests in India.



Life stages of mite and rice-locust and synchronization of biological profile

Thanks are due to Muslim Social Uplift Society, Sultan Jahan Manzil, Aligarh for financial support.

Reference

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Weight Loss in Maize Grains due to Insect Infestation in Different Storage Structures

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Field survey was carried out to assess the damage to stored maize grains in six developmental block viz., Nurpur, Rait, Kangra, Nagrota Bagwan, Panchrukhi and Baijnath of district Kangra, Himachal Pradesh during 1997-